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CORPS OF ENGINEERS  
U. S. ARMY

COMPREHENSIVE REPORT  
INVESTIGATION OF MILITARY CONSTRUCTION  
IN ARCTIC AND SUBARCTIC REGIONS  
1945-1948

APPENDIX II  
LIBRARY RESEARCH



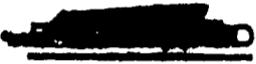
PREPARED BY  
ST. PAUL DISTRICT  
CORPS OF ENGINEERS  
FOR  
OFFICE OF THE CHIEF OF ENGINEERS  
AIRFIELDS BRANCH  
ENGINEERING DIVISION  
MILITARY CONSTRUCTION

JUNE 1950

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**COMPREHENSIVE REPORT**  
**INVESTIGATION OF AIRFIELD CONSTRUCTION**  
**IN ARCTIC AND SUBARCTIC REGIONS**

**APPENDIX II**  
**LIBRARY RESEARCH**

**I Introduction**

1. **AUTHORIZATION.** The project for the investigation of the phenomena of permanently frozen ground, as related to the construction of airfields in arctic and sub-arctic regions, was authorized by the Office, Chief of Engineers in a letter to the Division Engineer, Upper Mississippi Valley Division, SPENM (2 February 1945), Subject: "Investigation of Airfield Construction in Arctic and Subarctic Regions". The St. Paul District was designated as the investigational agency, with supervision by the Division Engineer to consist of inspections and reviews of programs, as deemed necessary, decisions with respect to major policies, and reviews of special and periodic reports. Direct correspondence between the investigational agency and the Office, Chief of Engineers was authorized. The approved "Comprehensive Program for Investigation of Airfield Construction in Arctic and Subarctic Regions", including library research, was received from the Office, Chief of Engineers with letter, SPEER (20 June 1945).

2. **PURPOSE.** The objectives of the program are to prepare a bibliography on permafrost and allied subjects and to collect published information on permanently frozen ground and construction thereon.

3. **SCOPE.** Data and information gathered from the beginning of the investigation in February 1945 and continuing through January 1949 are discussed in this report.

**II General**

4. **GENERAL.** Library research is an important part of the permafrost investigation. A large number of articles published in the English language and pertaining to permafrost and related problems have been examined during the study of various phases of the Permafrost Investigation. A bibliography listing these articles and publications is given in Section IV of this appendix.

5. **OTHER BIBLIOGRAPHIES.** The following bibliographies have been prepared by other agencies in connection with investigations they have in progress. Although many of these references do not pertain directly to permafrost, they often discuss allied subjects of interest in the study of permafrost.

- a. Arctic Warfare, A Bibliography, June 1946, The Engineer School, Fort Belvoir, Va.

- b. Arctic Warfare, A Bibliography: Supplement No. 1, June 1947, The Engineer School, Fort Belvoir, Va.
- c. Arctic Warfare, Bibliography of Reports and Technical Information, Supplement No. 1, 10 May 1947, The Engineer School, Fort Belvoir, Va. This bibliography is a supplement to "Arctic Warfare" published by The Engineer School, Fort Belvoir, Va., dated 28 October 1946. (Copy of bibliography dated 28 October 1946 has not been received in this office.)
- d. Bibliography of Arctic Literature with Glossary, Brochure No. 2, August 1948, prepared at The Engineer School, Fort Belvoir, Va., for the Chief of Engineers.
- e. Frost and Permafrost, A Brief Survey of the Agencies and Literature Dealing with Frost and Permafrost, September 1948, Robert W. Schmidt, Air University, Maxwell Field, Alabama.
- f. Bibliography on Frost Action in Soils. Bibliography No. 3, 1948, The Highway Research Board, 2101 Constitution Avenue, Washington 25, D. C.

6. **RUSSIAN BIBLIOGRAPHIES.** Section III, Russian Bibliographies, briefly discusses the work of The Stefansson Library and lists the Russian articles translated as well as those summarized. Bibliographies of Russian language articles prepared by other individuals and agencies are also shown.

### III Russian Bibliographies

7. **CONTRACT WITH THE STEFANSSON LIBRARY.** On 19 June 1947, this office entered into a contract with Dr. Vilhjalmur Stefansson, doing business as The Stefansson Library, Four Saint Luke's Place, New York 14, N. Y. The following work and services will be performed under the contract: (a) To conduct a search for all articles, pamphlets, reports, or other written material in the Russian or other foreign language dealing with the subject of permanently frozen ground in the arctic and subarctic regions, and construction, engineering and other problems related thereto; to analyze and review all such articles, pamphlets, reports, or other written material, and to summarize the contents thereof in semimonthly written reports in the English language, which reports shall identify the sources of all materials; (b) To furnish, upon request, complete and accurate English translations of any articles, pamphlets, reports, or other written material reported upon in the summary referred to in the previous paragraph, and of any articles, pamphlets, reports or other written material supplied for translation.

8. **WORK ACCOMPLISHED BY THE STEFANSSON LIBRARY.** To date, the Stefansson Library has furnished this office with summaries of eighty-nine articles and translations of seven articles. Translations have been received of the following Russian articles:

- (1) CHEKOTILLO, A. M., "The Underground Storage Places in the

Permafrozen Ground", Priroda, Vol. 11, 1946, pages 27-32

The author points out that the use of natural cold storage in permafrost areas generally has been limited to the local Russian and native population who have used small, unlined units. A description is given of large size (462 cubic meters) subterranean cold storage places constructed by the Russian Government at the Port of Ust-Yenisey, on the lower reaches of the Lena River and other places. Cold storage is an acute need in the Arctic and Subarctic during the summer. A bibliography of twelve titles is given.

- (2) FEDOSOV, A. E., "Prognosis of the Settling of Buildings Caused by Thawing of the Ground Under Their Foundations", Trudy of the Obruchev Institute of Permafrostology, Vol. IV, 1944, pp. 93-124

The author emphasizes the importance of developing methods of calculating the settlement of buildings constructed on thawing ground. In this problem, the contraction of the volume of ice and the settling of the mineral part of the ground are important points. Methods of computation are given. Bibliography of 8 titles is given.

- (3) OBRUCHEV, V. A., "The Fifteenth Anniversary of the Ground Frost Study of the Academy of Sciences of the USSR", Priroda, USSR Academy of Sciences Publication, No. 5, 1946

This article is a brief review of the study of permafrost beginning in Russia in 1845. The 100th anniversary is also the 15th anniversary of the establishment of a special commission for permafrost research. The commission became a special committee and is now the Institute for the Study of Ground Frost. Various definitions of terms are given. Reference is made to publications prepared in the 15 year period.

- (4) SUKHODOL'SKIY, E. I., "The Construction of an Earth Railroad Bed in the Northern Regions Under Permafrost Conditions", Trudy of the Obruchev Institute of Permafrostology, Vol. II, Moscow, 1945, pp. 27-7

Chapter VI - The Construction of Earth Railway Embankments

This is a discussion of Russian difficulties experienced in the construction of stable earth railway embankments in permafrost areas where the surface and subsurface soils are fine-grained, frost-acting, boggy materials.

- (5) SUMGIN, M. I., KACHURIN, S. P., TOLSTIKHIN, N. I., and TUMEL, V. F., "General Permafrostology", Academy of Sciences of USSR, Moscow, 1940, Chapters I through V

This is a major reference book prepared by the Obruchev Institute of Permafrostology to present, in condensed form, the results of research done to date. Five of the eight chapters have been translated.

Chapter I -- Introduction. Terminology. A Short History of Permafrostology, by Sumgin.

Chapter II -- Physico-mechanical Processes in Freezing and Frozen Ground, by Sumgin.

- Chapter III -- Seasonal Freezing and Thawing of the Ground in the Permafrost Area, by Tumel.
- Chapter IV -- The Region of Distribution of Permafrost and the Thickness of Permafrost Layers, by Tumel.
- Chapter V -- The Thermal Regime of the Ground in the Permafrost Area, by Sumgin.
- The following chapters have not been translated but are included to complete the chapter headings:
- Chapter VI -- Some Physical Properties of Frozen Ground, by Tumel.
- Chapter VII -- Genesis of Permafrost, by Tumel.
- Chapter VIII -- Degradation of Permafrost, by Sumgin.

- (6) TSYTOVICH, N. A., "The Unfrozen Water in Porous Strata", *Izvestia of Academy of Sciences, Geological Series*, No. 3, 1947, pp. 39-48

Under certain conditions, water does not freeze at temperatures below  $0^{\circ}$  C. In explaining some of the physico-mechanical characteristics of frozen ground, the possible existence of a certain amount of water in a liquid state must be assumed. Investigation shows the presence of unfrozen water in frozen ground down to a temperature of  $-194^{\circ}$  C. The quantity, contents and characteristics of unfrozen water on unfrozen ground are not constant and change with a change in conditions. A bibliography of 20 references is also given.

- (7) ZHUKOV, V. F., "Earthworks in the Construction of Foundations in the Region of Permafrost", Academy of Science, Obrucher's Institute of Permafrostology, Leningrad, 1946

This book is divided into 8 chapters as follows:

- Chapter I -- Introduction.
- Chapter II -- Preliminary Work.
- Chapter III -- Methods of Softening Permafrozen Ground.
- Chapter IV -- Methods of Removal of Excavated Earth.
- Chapter V -- Methods of Strengthening Trench Walls.
- Chapter VI -- Methods of Preliminary Preparation of Trenches for Construction of Foundations.
- Chapter VII -- Refilling of the Trenches.
- Chapter VIII -- Organization of the Earthwork.
- Chapters I, VI and VII have been translated. One point of interest is the use of the electro-chemical methods of solidifying permanently frozen ground. A table showing the depth of permafrost for different types of soils in various parts of Russia is also given.

#### 9. SUMMARIES OF RUSSIAN ARTICLES RECEIVED. Summaries have been received of the following Russian articles:

- (1) BARANOV, I. Y., "Methods of Charting the Permafrost", *Trudy of the Committee on Permafrost, Academy of Sciences*, Vol. 6, pp. 107-125, incl., Moscow 1938

This article discusses the various methods of mapping permafrost. These maps are made on scales of 1:5,000 to 1:500. It points out that for construction work, detailed maps showing the configuration of the surface of seasonal and permafrozen ground, water bearing

thawed ground, mechanical properties, thermal regime of the ground, degree of moisture, suitability of the site, etc., should be made. There is also a discussion of climate, geological structure, hydrogeology and vegetation. The author points out that drilling and test pits are necessary to obtain much of the desired information.

- (2) BILIBIN, U. A., "The Active and Passive Permafrost", *Izvestia of the Geographical Society*, No. 3, pp. 409-411, Moscow-Leningrad, 1937

This is a short article which discusses the origin of permafrost. The author cites two opposing theories. Permafrost is a product of the climate of some distant epoch and at the present time is gradually and constantly degrading; or permafrost is the direct result of present day climate. The author does not fully accept either point of view yet finds enough justification for each. He discusses the various phases of permafrost insofar as it occurs in Russia.

- (3) BIRKENGOF, A. L., "Some Observations on the Forest Cover and Permafrost", *Trudy of the Commission for the Study of Permafrost*, Vol. III, Leningrad, 1934, pp. 41-57 incl.

This article is based on the author's observations on permafrost conditions in the basin of the Indighirka River. He points out that the daurian larch is the dominant tree and, north of 67° latitude, the only tree. In the southern part of the basin, birches, poplars, and aspens are found in addition to the daurian larch. The author discusses his theories as to the lack of reforestation in the tundra and other factors concerning vegetation in permafrost areas. The author concludes his observations by a description of a "sunken lake" described as the result of the thawing of fossil ice.

- (4) BOGOSLOVSKY, N. N., "Shallow Foundations of Buildings with a Few Stories", an article in "Depth of Foundation Placement for Buildings with Few Stories in Conjunction with Seasonal Freezing of the Ground", *Institute of Permafrostology, Academy of Sciences, USSR, Moscow-Leningrad*, 1946, pp. 16-42

The author discusses the possibility of building small buildings of more than two stories with the basements or cellars on almost any ground since they can easily withstand small, uneven settlement. He points out that in these cases, it may be possible to avoid expensive and deep foundations. He states that the nature of the frozen ground, the nature of ground swelling, and the extent of swelling of various types of ground are factors which must be considered. The author states that the phenomenon of migration of moisture in the ground is of more importance than the freezing of the water in the pores of the ground. He lists twelve basic principles of foundation construction.

- (5) BONCHKOVSKY, V. F. and BONCHKOVSKY, U. V., "The Study of the Applicability of the Seismic Method for the Determination of the Upper Surface of Permafrost", *Trudy of the Commission on Permafrost*, Vol. V, Moscow, 1937, pp. 131-162

This is a rather detailed discussion of methods and equipment used

in the application of the seismic method for determination of the upper surface of permafrost. The author states that the seismic method is very dependable for determining depths of the upper surface of permafrost where the permafrost is near the surface. He also discusses other factors of the seismic method. A bibliography of two titles is given.

- (6) BUKREEV, P. A., "Waterproofing and Drainage of Defense and Non-Defense Constructions", Strojizdat Narkomstroja, 1943, pp. 3-124  
This book contains a description of the construction and methods of work most frequently used to protect construction work, completely or partly built in the ground, from surface and ground waters. He discusses the properties of subterranean waters and their origin; drainage works; methods of preventing the inflow of water into the construction work; methods of waterproofing; and special provisions against capillary action. A bibliography of 51 titles is included.
- (7) CHEKOTILLO, A. M., "Gigantic 'Naled' or Icings of Northeastern Siberia", Nauka i z hizr, No. 1, pp. 26-29, Moscow, 1945  
The author describes the peculiar arctic phenomenon known in Russian literature as "naled" and throughout Siberia by the Yakut term "taryn" and called "icing" in English literature. River "naleds" are formed as a result of the freezing of the shores and the increase of the thickness of ice covering. The water under the ice seeks an outlet and once having broken through, it spreads along the surface and freezes. A similar process takes place during the formation of ground "naleds". In spite of the abundance of water in the summer in rivers and lakes in Siberia, the problem of water supply in the winter is difficult. A study is being made to determine the possibility of using the underground water supply of the naleds to provide a dependable water supply for mining and other purposes.
- (8) CHEKOTILLO, A. M., "Measures Against 'Naledi' (Icing)", Priroda, 1946, No. 1, pp. 20-28  
This article discusses various measures to prevent icing. These include drainage, seasonal or permanently frozen belts, temporary or permanent obstructions, changing of the water course, enlargement of excavated areas, and the change of construction location. The application of various items to prevent icing is discussed in detail. A bibliography of 21 titles is given.
- (9) CHEKOTILLO, A. M., "The Use of Snow, Ice, and Frozen Ground for Construction Purposes", Academy of Sciences of the USSR, pp. 2-62, 1945 (illustrations)  
This article is intended to familiarize engineering circles with the technique of construction which utilizes snow, ice and frozen ground. The various methods of using snow and ice and frozen ground for construction purposes is discussed in detail. A bibliography of 76 titles is included.

- (10) CHEKOTILLO, A. M., "Five Years of Construction and Use of Ice Storage Houses", Obruchev Institute of Permafrostology, Leningrad, 1946, pp. 3-79

This brochure summarizes the experience gained through the construction and utilization of ice storage houses in the USSR. The author discusses the method of construction of ice houses, dimensions, site selection, etc. He also points out the defects in the original plans and details of construction for new types. Repairing and winter cooling of the storage houses are also discussed. Facts and figures on the preservation of various types of vegetables is included. A bibliography of 9 titles is given.

- (11) CHEKOTILLO, A. M., "Naledi (Icings) and Measures Against Them", Obruchev Institute of Permafrostology, pp. 5-131, Moscow, 1940

This book represents an attempt to collect and systematize existing material on the question of measures of combating the phenomenon called by the Russian "Naled" (plural Naledi). The book is divided into the following chapters: Process of formation of the "Naled" and the phenomenon caused by it; The value of water pressure in naled; The snow cover as a factor in the formation and activity of naled; The effect of naled on engineering construction; History of development of measures against naled, where the author summarizes the methods up to 1928; Modern methods of combating naled. A bibliography of 20 titles is included.

- (12) CHIRIKHIN, U. D., "The Permafrost in the Basin of Indighirka River", Trudy of the Commission for the Study of Permafrost, Vol. III, Leningrad, 1934, pp. 21-39

This article is based partly on the results of an investigation by the Academy of Sciences in 1929-30. It discusses in detail the naleds and icings in the Indighirka River. The author points out that the amount of feed water from moisture from the thawed horizon above the permafrost depends on (1) amount of water in the ground which depends on the amount of precipitation prior to freezing, (2) the temperature of the air at the start of freezing, and (3) the amount of the first snow.

- (13) DOSTOVALOV, B. N., "The Electrical Characteristics of the Frozen Formations", Trudy of Obruchev's Institute of Permafrostology, Vol. V., Moscow, 1947, pp. 18-35

A description of the methods and results of investigations of several authors is given. The author emphasizes the importance of the utilization of electrical characteristics of various formations in addition to petrographic classification. He concludes with a series of recommendations for further research. A bibliography of 25 titles is included.

- (14) DURDENEVSKAYA, M. V., "The Ancient Glaciation and Contemporary Permafrost in the Irkut-Baikal Depression", Trudy of the Commission for the Study of Permafrost, Vol. III, Leningrad, 1934, pp. 89-105  
On the basis of published material cited in considerable detail,

the author concludes it is possible to establish the former existence of glaciation of the Alpine type on the mountains surrounding the valley. In the appendix to the main article, the author gives detailed geological descriptions of the valley in question with mechanical analysis of the sand and a geological map of the valley. A bibliography of 7 titles is included.

- (15) DZENS-LITOVSKY, A. I., "Mineral Lakes Under the Permafrost Conditions", Trudy of the Committee on Permafrost, Academy of Sciences, Vol. 6, pp. 79-103 incl., Moscow, 1938

This article is devoted to characteristics and genesis of mineral lakes in the Trans-Baikal region of Siberia. Some of these lakes abound in mineral salts including mirabilite, sodium-chloride, and soda. The author states that under the permafrost condition, the regime of the mineral lakes acquires a peculiar character. The author discusses formation of mineral lakes as well as the formation of fresh-water lakes with particular reference to permafrost. He also points out that chemical weathering takes place more intensely under the climatic conditions of permafrost which also produces greater mechanical weathering on various formations. A bibliography of 29 titles is given.

- (16) EFIMOV, A. I., "Deep Freezing of the Ground and the Regime of the Waters Above the Frozen Ground Under Heated Buildings", Trudy of the Obruchev Institute of Permafrostology, Vol. IV, pp. 205-225, Moscow-Leningrad, 1944

This paper is the result of observations and experiments conducted by the Trans-Baikal Expedition of the Obruchev Institute of Permafrostology in 1941-43. The author describes the geological structure of two sections and gives a schematic diagram of thawing observed in 1942, together with the resultant pressure of water. A description of the character of permafrost conditions in this area is given as well as data about the seasonal freezing and thawing of the ground. The author gives the temperature conditions of ground under heated buildings, the variation of the depth of freezing of water and its temperature, and discusses the hydrological characteristics of the area. The author concludes that, in general, where there is water above the permafrozen ground, building is very difficult, as preventive measures are not yet completely worked out. A bibliography of 10 titles is included.

- (17) ENENSTEIN, B. S., "The Results of Application of Electrometrical Investigation by Direct Current in the Region of Permafrost", Academy of Sciences, Obruchev's Institute of Permafrostology, Vol. V, pp. 36-86

In this article, the author discusses the application of direct current for investigations in the region of permafrost. The work is divided into 12 chapters. Its three aims are given as (1) to demonstrate the fallacy of the current conception that the permafrozen formations are not conductive of electrical

current; (2) that both theoretical and experimental data about the water in frozen formations give us sufficient reason to believe that the permafrozen formations must be semiconductive; and (3) that laboratory and field investigations fully confirm the above statement. The author, in the first part of his work (3 chapters), discusses the electrical conductivity of formations in place. In the second part (9 chapters), he gives a critical review of investigations by electrical methods which have been made in the region of permafrost. A bibliography of 33 titles is given.

- (18) ENENSTEIN, B. S., "The Observation Under Natural Currents (spontaneous polarization) in the Permafrozen Layers in the Igarka Region", Academy of Sciences, Obruchev's Institute of Permafrostology, Vol. V, pp. 87-92

The author describes the results of field work of a geophysical expedition of the Obruchev Institute of Permafrostology in the region of Igarka in 1940 where observations were made on the natural electric current existing within the limits of the active layer. He cites the only previous work on this subject done by K. P. Kozin in the Chata region. The author describes a new design of nonpolarized electrode which can be easily made under field conditions. One reference is cited in this article.

- (19) ERMILOV, I. Y., "Some Peculiarity of River Deposits of Northwestern and Northern Siberia", Academy of Sciences, Trudy of the Polar Committee, Vol. 20, pp. 27-33, Leningrad, 1935

A small portion of this article pertains to permafrost. The author indicates that, under permafrost conditions, the interlayer of vegetable remains and mineral soil is tightly cemented by freezing and takes the form of lenses of considerable size. The excellent state of preservation of vegetables under permafrost conditions is due to the almost complete absence of chemical weathering which, as a rule, occurs by means of moving groundwater. Thus, the permafrost of northern Siberia is an important factor influencing geological processes, causing the formation of alluvial deposits including a large quantity of vegetable and animal remains. The preservation of carbonate salts in permafrozen sea and river deposits is also due to permafrost conditions.

- (20) FEDORTSEV, V. A., "Permafrost and Naleds in the Northeastern Yakut Region", Trudy of the Committee on Permafrost, Vol. IV, Moscow, 1935, pp. 93-104

The material for this article is based on observations made by the author in geological investigations in the northeastern portion of the Yakut region. Two shafts, a deep pit, and numerous trenches were dug and temperature observations were made both during the course of excavations and afterwards. The author gives three tables of temperature observations and a map showing the location of the points where the work was

done. The second portion of this article is devoted to the author's observations on several naleds. He distinguishes ground and river naleds as well as seasonal ones and those of long duration. The article concludes with a detailed description of a large naled located on the Taryn-Tustja River, the left tributary of the Dogdo River.

- (21) GLAZOV, N. V., "The Method of Studying the Degradation of Permafrost", Trudy of the Committee on Permafrost, Vol. IV, pp. 155-161, Moscow, 1938

The author states that the degradation of permafrost has not received sufficient study. He points out that observations of the "island type" of permafrost will supply the desired information but will require a long period of observations. As an alternative, he suggests observations on those traces which freezing and thawing leave in the ground such as the sinking of the ground, the infiltration and chemical effect of soluble salts in the ground, and the difference in salt concentration and coloration of the ground.

- (22) GRAVE, M. A., "The Fossil Ice in the Lena-Aldan Water Divide", Trudy of the Obruchev Institute of Permafrostology, Vol. IV, Moscow, 1944, pp. 10-32

The author emphasizes the importance of the study of fossil ice from the practical point of view as a phenomenon which, with the change of thermal balance of the surface, may cause a considerable deformation of the surface. In 1940, the Yakuts expedition of the Obruchev Institute began a study of the fossil ice in the region of a salt lake, Abalakh, which is situated at the Lena-Aldan water divide. The author states that the fossil ices of this locality may be divided into two groups: buried ice, and the mass of ice formed within the ground. The author cites a series of observations of the temperatures of the ground and fossil ice in a 32 meter deep pit which was located on the western shores of Lake Abalakh where there was fossil ice 22.75 meters thick. In conclusion, the author suggests the method of mapping the fossil ice which, worked on a very small territory, would permit, by prognosis, mapping the occurrence of it in a very large territory. Bibliography of 25 titles is given.

- (23) GRIGORIEV, A. A., "The Sub-Arctic", The Institute of Geography, Academy of Sciences of the USSR, Moscow-Leningrad, 1946, pp. 3-161

Most of the material on permafrost in this work is in Chapter 3 where the author examines, in detail, the permafrost as a factor of the geomorphological process, and the character and behavior of rivers and lakes under permafrost conditions. However, through the work are scattered references to permafrost and its relation to flora, fauna, and the process of soil formation. Six pages of bibliography are included.

- (24) ITTER, Y. V., "The Thickness of the Layer of Ever Frozen Ground in the Region of Verkhoyansk", Problems of the Arctic, No. 6, Leningrad, 1939

This is a short note reporting some of the results of the mining expedition of 1938 which was conducted in the Yana River region, 90 km below Verkhoyansk. In a cut 40 meters deep, a series of temperature observations were made on the layer of permafrozen soil. This layer was formed of gravel-pebbly sand of the Quaternary age. The author concludes that (1) the belt of constant temperature lies at the depth between 10-15 meters; (2) geometrical gradient is about 25 meters; and (3) the depth of the permafrozen layer is equal to  $25 \times 7.2$ , plus 12, or in round figures, 200 meters. A table of temperatures at various depths is given.

- (25) KACHURIN, S. P., "An Attempt to Subdivide into Regions the Grounds in the European Territory of the USSR in which the Phenomenon of Seasonal Freezing Occurs", Article in "Depth of Foundation Placement for Buildings with a Few Stories in Conjunction with Seasonal Freezing of the Ground", Institute of Permafrostology, Academy of Science, USSR, 1946, pp. 43-63

The author emphasizes the practical importance of seasonal freezing of the ground, and the necessity for systematic plotting of its distribution. A schematic map of the various depths of freezing of the ground is given, but the author stresses its inadequacy and gives a method for gathering material for a revised schematic map which would give a much fuller picture of the problem. The Institute of Permafrostology, at the initiative of the late M. I. Sumgin, organized the collection of factual material which forms the basis of this article.

- (26) KHOMICHEVSKAJA, MME. L. S., "The Compressive Strength of Ice and Permafrozen Ground under Natural Conditions", Trudy of the Committee on Permafrost, Vol. X, Moscow, 1940, pp. 37-83

The necessity of rechecking the results of laboratory experiments on permafrozen ground under natural conditions resulted in a series of experiments which a group of scientists of the Committee for Permafrostology conducted in 1937 in the Tajmir Peninsula. The author describes some differences in methodology and the processes of experimentation. Two large and very detailed tables on these investigations provide comparison with the work of three other authors. A bibliography of eight titles is given.

- (27) KONDRAT'EVA, A. S., MME., KRAGEL'SKIJ, I. V., and SHAKHOV, A. A., "Increase of Snow Density under the Compressing Load", from "Physico-Mechanical Properties of the Snow and Their Use in Airdrome and Road Construction", Academy of Sciences of USSR, Moscow-Leningrad, 1945, pp. 5-9

This work is the result of field and laboratory investigations by the authors, designed to determine the relationship between the specific pressure applied to the snow cover and its density. The authors give six diagrams illustrating the relationship between

density and pressure at varying temperatures, at constant temperatures, at varying temperatures and constant pressure, etc. Formulas are given for the relationship of density to pressure at varying temperatures as well as at constant temperatures. A formula for the distribution of density in depth is given. The authors reach the following conclusions: (1) the ability of snow to become more compact under pressure depends upon the temperature of the snow; (2) practically, it is best to subject snow to packing at a temperature near zero; and (3) it is best to subject snow to packing in thin layers because pressure considerably decreases in depth with an increase in distance from the point of its application.

- (28) KORIDALIN, E. A., "The Possibility of Application of Seismic Investigations for the Study of Permafrost", Trudy of the Commission for the Study of Permafrost, Vol. III, Leningrad, 1934, pp. 13-19 incl.

The author states that the method of immediate observation by drilling or pit sinking for the study of permafrost is both expensive and limited to the specific area of investigation. Consequently, other physical methods which utilize specific characteristics of various soils (the electric, magnetic, gravitational, and seismic methods) are used, the seismic method forming the subject matter of this article. The principle of seismology is based on the rate of transmission of vibration waves, both longitudinal and transversal. Specifically, for the study of permafrost, the seismic method can be used to determine the subterranean relief and geological structure of layers adjacent to the surface of the earth. The author concludes with the suggestion of application of this method for the study of fossil ice.

- (29) KRAGEL'SKIJ, I. V. and SHAKHOV, A. A., "Change of the Mechanical Properties of Snow Cover in Time (Hardening)", from "Physico-Mechanical Properties of the Snow and Their Use in Airdrome and Road Construction", Academy of Sciences of the USSR, Moscow-Leningrad, 1945, pp. 10-13

One of the most unusual qualities of snow is the increase of its firmness in time, after mechanical action. This is the result of the process of recrystallization which takes place in the snow. From the point of view of this article, it is important to analyze, not the growth of crystals in time and number of centers in which the growth takes place, but the sum total result of this process which manifests itself in the increase in hardness, due to the joining of crystals formerly isolated and separated by a film of a.i.r. The experiments conducted by the authors show that at times the growth of hardness takes place 10-20 hours or more after the mechanical action. The authors give three graphs illustrating the increase in hardness at various temperatures and pressures, and hardening of the snow after the action of wooden rollers. Two tables illustrate the change in hardness of the snow in time, after mechanical action.

- (30) KRAGEL'SKIJ, I. V., "Methods of Determining Hardness and Compactness of Snow Cover", from "Physico-Mechanical Properties of the Snow and

Their Use in Airdrome and Road Construction", Academy of Sciences of the USSR, Moscow-Leningrad, 1945, pp. 61-66

The properties of snow cover change constantly in time. Usually the hardness of a material is estimated by sinking a point of specific form (ball, cone or pyramid) into it. The author states that the flat form now used for snow is not accurate since the results depend on the size of the stamp. In conclusion, the author states that with the fall in temperature, the hardness of snow increases and this increase is greater with a greater degree of density, i.e., while the hardness of snow with a density of 0.2 increases very little with the fall of temperature, it increases sharply for snow with a density of 0.4 to 0.5. There are 5 charts and illustrations.

- (31) KRYLOV, M. M., "Isothermic Ice Warehouses", Obruchev Institute of Permafrostology. pp. 3-77, Moscow-Leningrad, 1942

This book, issued by the Institute of Permafrostology, shows methods of utilizing natural winter cold for construction and use of ice storage houses. The work is divided into 5 chapters dealing with general data, construction, calculation of temperature, maintenance of ice warehouses, and conclusions. There is a bibliography of 22 titles.

- (32) KRYLOV, M. M., "Typical Design for an Ice Warehouse, as Prepared by the Engineer M. M. Krylov, with a Capacity of 135 Tons of Pickles in Barrels or 185 Tons of Potatoes", The Peoples Commissariat of Trade, pp. 1-33, Moscow, 1943

This pamphlet contains 17 pages of detailed drawings covering construction of an ice warehouse proposed by Krylov in co-operation with the Obruchev Institute of Permafrostology. The notes accompanying the drawings deal with the general construction, insulation, framing, sheathing, and illumination. There is also a chart showing the average cost and time involved in construction.

- (33) KUSHEV, S. L., "The Permafrost in the Lower Reaches of the Lower Tunguska River", Trudy of the Commission for the Study of Permafrost, Vol. III, pp. 73-88, Leningrad, 1934

This paper is the result of geomorphological and permafrostological observations by the author made during the summer of 1932. A series of test pits and trenches were made with temperature observations every 50 cm in the thawed ground along the south walls of the trench and in the frozen ground in special bore holes. The author discusses the valley of the lower Tunguska and breaks it into two parts. One of them is the plateau region and the other is a terrace composed of laminated sands underlain by gravels. The author gives a series of tables and cross sections and concludes that the region of the Yenisei Valley of the lower Tunguska has permafrost of the island type. A bibliography of 3 titles is given.

- (34) LAVROVA, M. A., MME., "The Presence of Permafrost in the Region of the Volch'ye and Moncha Tundras, on the Kola Peninsula", Trudy of the

Commission for the Study of Permafrost, Academy of Sciences, USSR, Vol. 3, Leningrad, 1934, pp. 117-210

This paper reports on some observations made by the Kola expedition which studied primarily the Quaternary of the Volch'ya and Monch tundras. A series of peat mounds found in the Volch'ya Lake at a distance of 14 to 15 meters from the shore are cross-sectioned. Permafrost usually lies at a depth of 40 to 42 cm from the top of the higher mounds and 30 to 35 cm from the top of the lower mounds. The author considers this permafrost to be of recent origin. In conclusion, the author states that permafrost is encountered north of the forest zone under favorable conditions and that it was found sporadically in small islands in peat mounds and was completely absent in the forest zone in mineral grounds.

- (35) LIVEROVSKY, A. V. and MOROZOV, K. D., "Constructions Under Permafrost Conditions", Leningrad, Moscow, 1941, pp. 1-244

This book represents a summary of the most pertinent information relating to the construction of industrial buildings and private dwellings. It is written by two specialists and consists of seven chapters subdivided into 22 sections and contains 151 drawings, illustrations and maps. Chapter headings include general data on permafrost, deformation of engineering construction under permafrost conditions, and methods of investigation in surveying for the construction of buildings under permafrost conditions, basic instructions and considerations for stable construction, consideration of the maintenance of constructions under permafrost conditions, and remarks on scientific investigations and experiments. A bibliography of 2 titles is included.

- (36) LUKIN, G. O., "Construction and Care of the Foundations under Small Industrial Buildings in the Dudinka Region", Trudy of the Obruchev Institute of Permafrostology, Vol. I, pp. 27-101, 1946

This article contains 18 tables, 50 diagrams and illustrations. It is the result of an investigation and study of methods of construction and utilization of small industrial buildings on the Taimyr Peninsula by a special group of permafrostologists. General characteristics of the region are given and include topography, temperature and precipitation, and winds. Observations conducted during the construction of the Dudinka electric power station are shown. Observations are also shown of a temporary electric power station and a brick factory. These observations consider the nature and occurrence of permafrost.

- (37) MEISTER, L. A. and MEL'NIKOV, E. I., "The Adfreezing Forces Acting Between Permafrozen Ground and Wood or Concrete and the Resistance to Shear of Permafrozen Ground under Field Conditions", Trudy of the Committee on Permafrost, Vol. X, Moscow, 1940, pp. 85-108

This author summarizes the results of field investigations carried on at the Igarka permafrost station by the Committee on Permafrost of the Academy of Science, USSR. As stated in the title, the study included the adfreezing forces of ground to wood and

concrete and the resistance to shear of permafrozen ground under natural conditions.

- (38) MORDVINOV, A. I., "The Relief and the Permafrost of the Left Bank of the Middle Course of the Byssa River, and the Adjoining Hills of the Southern Slopes of the Turanian Mountain Chain", Trudy of the Committee for Permafrostology, Vol. IX, pp. 57-133, 1940

The author discusses the general character of the topography of the area together with the occurrence of permafrost, drainage, ground temperatures, frost mounds, and interrelation of permafrost, and topography. A bibliography of 71 titles is included.

- (39) NEDOKUCHAEV, N. K., "The Soil and Conditions for Agriculture, Pasture Lands and Truck Farming in the Yakut A.S.S.R.", Academy of Sciences, Trudy of the Council for the Study of Resources, the Yakut A.S.S.R., Vol. 4, Leningrad, 1932, pp. 1-103

A small portion of this lengthy article, devoted to the description of the soils of the Yakut region, deals with the permafrost conditions and their relation to agriculture. A point of interest is the fact that the author states that permafrost is a positive factor for agriculture in this region inasmuch as, in view of the scant precipitation in the summer, the permafrozen ground being impervious to water, serves to preserve the supply of spring snow water and summer precipitation. Without this factor, this region would be a desert.

- (40) OBRUCHEV, V. A., "Progress of Permafrostology in the USSR", (Obruchev in Memorial Volume by the Academy of Sciences dedicated to the Thirtieth Anniversary of the October Revolution, Part 2, pp. 217-237, Moscow, 1947

This article is one of a series of short papers included in two memorial volumes summarizing the progress of various branches of Soviet science for 30 years of the Republic's existence. This paper discusses the history of the permafrost investigation and includes a discussion of general permafrostology, distribution of permafrost, characteristics of the permafrozen mass, division of the permafrost areas into regions according to temperature, thickness of permafrost, degradation of permafrost, fossil ice, nales, regime of water in permafrozen areas, seasonal freezing, physico-mechanical properties of frozen ground, and engineering permafrostology.

- (41) OBRUCHEV, V. A., "The Work of the Obruchev Institute of Permafrostology in 1945", Academy of Sciences of the USSR, Division of Geological and Geographical Sciences, Moscow, Leningrad, 1947, pp. 152-173

This article points out that during 1945, the Institute of Permafrostology was occupied with 3 major problems: (1) genesis of permafrost, the theory of the freezing process; (2) conditions of stable construction under permafrost conditions; and (3) seasonal freezing and seasonal reserve of cold. The study of regional permafrost is covered by 12 chapters which include observations in the region of Khal'mer-U (European

Russia), thermokarst lakes of the Yakut, Baikal, Amur, Kolyma, Anadyr, Far East, and Manchuria. Observations deal with the general study of general permafrostology. Construction under permafrost conditions is dealt with in 5 chapters. Three chapters deal with seasonal freezing; two with noleds. Ground temperatures are considered in 2 chapters. Five chapters deal with such aspects of permafrost as the thermal properties of the ground, migration of water in frozen ground, and ice storage. A list of 16 articles published in 1945 is included.

- (42) OBRUCHEV, V. A., "The Work of the Obruchev Institute of Permafrostology in 1944", Academy of Sciences of the USSR, Division of Geological and Geographical Sciences, 1945, pp. 114-132

This article is a review of the work accomplished by the members of the Obruchev Institute of Permafrostology during 1944. In addition to the material published during this year (1944), 41 papers by 29 different authors were submitted for later publication. In 6 instances, the papers represent the work of a group of scientists, as many as 7 in number. Eight papers deal with the various aspects of construction of building foundations in permafrost areas. One paper deals with canalization under permafrost conditions. One paper deals with coal mining. Five papers deal with problems of construction of airfields in the areas of permafrost. One paper deals with the method of construction of snow galleries for the protection of roads. One paper deals with storage houses made of ice. One paper describes ice and its properties. Three papers deal with frozen ground. Eight papers deal with seasonal freezing. Two papers deal with frost mounds and permafrost. Several other papers deal with the use of electro-magnetic waves in analysis of rock formations, hydrological observations, methods of increasing vegetable crops, etc., all under permafrost conditions. One paper deals with the method of salt extraction in the Yakut USSR by means of freezing. Many of these papers as set forth in this article are abstracts of the papers as published originally.

- (43) OBRUCHEV, V. A., "One Hundredth Anniversary of the First Expedition of the USSR Academy of Sciences for the Study of Permafrost", *Izvestia of the All Union Geographical Society*, Vol. 78, Parts 5-6, pp. 439-474, 1946

The author describes the expedition of A. F. Middendorf as the first scientific attempt to study permafrost. Middendorf left St. Petersburg on 14 November 1842 and returned from Siberia on 1 April 1845. His expedition studied organic sea life far from the shores of the Taimyr Peninsula, and verified the presence of frozen ground discovered by local settlers while digging a well at Yakutsk. Obruchev points out that after this preliminary work had been accomplished, nothing was done for the 85 years intervening between 1845 and 1930 when the study of permafrost was again resumed.

- (44) OBRUCHEV, S. V., "Solifluctional Terraces and Their Origin Based on Studies in the Chukotsk Region", from "Problemy Arktiki", No. 3, pp. 27-

48, and No. 4, pp. 47-83, 1937

The author proposes, on the basis of his observations in the Chukotsk region, to discuss the origin of solifluction (high) terraces which have been found by previous investigators, usually in the region of bald peaks of a number of Siberian mountains. In the Chukotsk area, they are found in a wide belt of the shore mountains stretching for more than a thousand kilometers from the Kolyma River in the west to Koluchinskaya Guba in the east. The author discusses the various theories of the origin of the terraces and proposes a new theory of his own. A bibliography of 52 titles is included.

- (45) PETROV, V. G., "The Attempt of Calculating the Pressure of Ground Waters in the Naleds (Ice Frostings)", *Trudy of the Commission for the Study of Permafrost*, Vol. III, Leningrad, 1934, pp. 59-72 incl.

The article is devoted principally to a description of a field experiment conducted at the Skovorodino permafrost station on the Amur-Yakutsk Railway in 1930-31. The author describes a triple action apparatus which measures the pressure of the water in a naled mound. He states that the pressure equaled 52 atmospheres in this particular instance.

- (46) PETROVSKY, A. A., "Analysis of Observations of Capacity Made With the Use of Horizontal Antenna", *Trudy of the Obnukhin Institute of Permafrostology*, Vol. V, pp. 93-119, Moscow, 1947

This highly technical article is devoted to the mathematics of calculations of the capacity of antennas. The validity of the formulas has been subjected to a check during experiments conducted near Moscow in 1935. The author gives a series of graphs to simplify the computations. Bibliography of 5 titles is given.

- (47) PETROVSKY, A. A. and DOSTOVOLOV, B. M., "The First Experiments of the Transmission of Electromagnetic Waves Through the Permafrozen Layers", *Trudy of the Obnukhin Institute of Permafrostology*, Vol. V, pp. 121-160, Moscow, 1947

This article deals with the study of the transmission of electromagnetic waves through the mass of permafrost and with the work of an expedition to Igarka in 1940. Igarka is the site of a special experimental station for the study of permafrostology. In addition to other information, it was stated that the shorter wave penetrates the frozen ground a great deal easier than the long one. Bibliography of 10 titles is given.

- (48) PETROVSKY, A. A. and DOSTOVOLOV, B. M., "Application of the Wave Lengths Method for the Study of the Upper Layer of the Ground", *Trudy of the Obnukhin Institute of Permafrostology*, Vol. V, pp. 161-174, Moscow, 1947

The author states, on the basis of his work reported elsewhere, that the wave length method can be used for the electric mapping of the geological structure of the upper surface of the earth

along two lines: the dielectric constant and the specific resistance. The author discusses results of experiments made in Moscow, over the ice in Lyublino near Moscow, and the work in Igarka. Six diagrams are given to illustrate why the application of horizontal antenna to determine the upper thickness of the layer can give good results only when the upper layer has a small dielectric constant. A bibliography of 5 titles is given.

- (49) PETROVSKY, A. A., "Determination of the Lower Limits of Permafrost by the Electrometric Methods", Trudy of the Commission for the Study of Permafrost of the Academy of Sciences of the USSR, Vol. III, Leningrad, 1934, pp. 5-11

This article deals with the results of achievements during the 3-1/2 years of study of application of electrical methods for the determination of the thickness of permafrost. It is interesting to point out that the best results were obtained at night when the surface of the ice was frozen. During the day, a thin layer of water was formed on the surface of the ice which increased the capacity and disrupted the observations.

- (50) PODOL'SKI, V., "Experience of Excavation in Mining in the Arctic under Permafrost Conditions", Problems of the Arctic, No. 4, pp. 79-82, Leningrad, 1939

This article cites the results of experiences of mining under permafrost conditions. All mining, both surface and underground, requires the use of explosives under permafrost conditions. Because of the difficulty of transportation and the extremely low temperatures, the choice of explosives is important. The author states that ammonite in capsules is the best type of explosive for this purpose.

- (51) PONOMAREV, V. M., "The Study of Permafrost in 1936", The Soviet Arctic, No. 2, pp. 111-112, Moscow, 1936

The author states that prior to 1935, little work had been done in the territory served by the Department of the Northern Sea Route. In 1936 three new permafrost stations were established at Anadyr, Yakutsk, and Amderma. Additional work was planned at other stations.

- (52) POVKH, I. L., "The Permafrost Conditions in the Village of Samarova on the Orb River", Trudy of the Permafrost Committee, Vol. 9, pp. 150-162, Leningrad, 1940

This article deals with the discovery of permafrost conditions in the village of Samarova in the region of the Orb River. The author concludes that the permanently frozen ground is of recent origin inasmuch as the layer of ground has been recently deposited as the result of considerable shifting of the Irtysh River bed.

- (53) RABOTNOV, T. A., "The Flora of the 'Naleds'", Izvestia Geographical Society, No. 3, pp. 395-408, Moscow-Leningrad, 1937

This is the report of the investigation in the basin of the upper

part of the Aldan and Timpton Rivers in the Yakutsk ASSR. The conclusions cite the wide distribution of low shrubs as a factor of the peculiar ecological conditions typical for tundra flora yet connected genetically with the forest areas. The author considers the shrub birch more ancient than other low scrub vegetation and a relic of the ice age, and points out the economic value of the low shrub area for reindeer breeding. Bibliography of 14 titles is given.

- (54) REDOZUBOV, D. V., "Laws Governing the Regularity of the Temperature Field in the Permafrost Region at Vorkuta", Trudy of the Obruchev Institute of Permafrostology, Vol. I, Moscow, 1946, pp. 137-166

This article consists of 2 parts. Part one deals with the laws of temperature in the permafrost region and part two deals with the application of these laws to specific conditions at Vorkuta. The author emphasizes the importance of the detailed study of temperature curves to determine the existence of permafrost degradation. Bibliography of 9 titles is given.

- (55) RICHTER, G. D., "Notes on Peat Mounds in the Region of Nudozero Lake", Trudy of the Commission for the Study of Permafrost, Academy of Sciences, USSR, Vol. 3, Leningrad, 1934, pp. 121-126

This paper is the result of observations made during the work of the Kola Peninsula expedition.

- (56) ROCHLIN, M., "Small Excavations Under Permafrost Conditions by Means of Explosives", Problems of the Arctic, No. 2, pp. 221-223, Leningrad, 1938

This brief article describes the experiences of the first Chunksk geological expedition which conducted a survey of permafrost conditions in the Chunksk Gulf region between latitudes 69°-70° N. The author describes the method of thawing the top of ground by burning oil on the surface and the use of explosives.

- (57) RYABUKHIN, G., "Certain Manifestations of Permafrost in the Region of Ust-Port", Problems of the Arctic, Vol. 6, pp. 82-85, Leningrad, 1939

This article deals with some observations on the character and manifestation of permafrost in the region of Ust-Port conducted during the oil prospecting in this region in 1939. The author gives a detailed description of the geological structure of the locality including frost blisters and frost heaving. He also points out the difficulty with thawing during the drilling of the oil well. This damaged the drilling machinery. No difficulty was encountered in drilling through the permafrost. Bibliography of 3 titles is given.

- (58) SALTUKOV, N. I., "Building Foundations in the Region of the Bolshezemelskaya Tundra", Trudy of the Obruchev Institute of Permafrostology, Vol. IV, pp. 124-204, Leningrad, 1944

This lengthy article deals with the author's observations and general conclusions pertaining to the peculiar problems of building in the everfrozen ground of the Bolshezemelskaya Tundra in the Vorkuta coal region. The author's conclusions

deal with selection of the best type of foundation, its depth, type of building, and expected result from the underlying frozen ground.

- (59) SALTYKOV, N. I., "Canalization Under Permafrost Conditions", Academy of Sciences, Obruchev's Institute of Permafrostology, Leningrad, 1944, pp. 1-51

This article discusses the construction of a sewer system at one of the experimental stations in the extreme north of the European part of the USSR. In conclusion, the author states: (a) the sewer system under permafrost conditions demands the application of special measures during the initial period of its operation such as artificial heating or the addition of water; (b) the same methods of thermal calculation can be applied to both the water supply and sewer system; (c) temperature of the sewage at the outlet should be near plus 1°C; (d) the size of the sewer system will be determined by the minimum number of buildings which will be served by the system; (e) where sewage flow is small, a continual check on operation is necessary; and (f) further work must be done to determine heat loss in such materials as wood when used at shallow depths for pipes. Bibliography of 8 titles is given.

- (60) SALTYKOV, N. I., "Building Foundations in Yakutsk", Trudy of the Obruchev Institute of Permafrostology, Vol. I, pp. 102-136, 1946

This article describes the deformation of buildings in the city of Yakutsk and gives an analysis of the deformation. The following conclusions are reached: In buildings with the basements or cellars constructed directly on the natural or filled-in ground, some local thawing takes place even under the cold climatic conditions of Yakutsk. In the construction of heated buildings, the use of a warm double floor and an ordinary basement, of .4 to .5 meters high, is sufficient to preserve the permafrost. An empty space must be left under the floor to preserve the permafrost under industrial buildings with higher than normal temperatures. Open or ventilated cellars and basements should be used. A bibliography of 9 titles is added.

- (61) SHIMANOVSKY, S. B., "Observation on the Soil Temperature in the Town of Yakutsk", Trudy of the Permafrost Committee, Vol. 10, pp. 155-160, Leningrad, 1940

The author describes the results of soil temperature observations conducted in Yakutsk.

- (62) SHVETZOV, P. F., "Permafrost and the Engineering and Geological Conditions of the Anadyr Region", Publication of the Glavsevmorput (The Main Northern Sea Communications Department) of the Sovnarcorn of the USSR, Leningrad, 1938, pp. 3-78

This article deals with the study of the Anadyr region including permafrost, groundwater, etc., and characterization of the ground with a view to determining the suitability for construction.

- (63) SHVETZOV, P. F., "The Role of Permafrost and Subpermafrost Waters in the Hydrology of the Basins of the Rivers Indigirka and Yana", *Izvestia of Academy of Science of the USSR, Geological Series*, No. 6, 1946, pp. 137-152

This article is devoted to the peculiarities of the water runoff in the basin of the Indigirka and Yana Rivers. The author states that the hydrological peculiarities of the region are factors of the permafrost as well as meteorological conditions. The origin of water underneath the permanently frozen ground, which feeds the icings and rivers, is not clear. More work must be done on this subject. A bibliography of 22 titles is given.

- (64) SIZOV, V. N., "Construction Work Under Winter Conditions", *People's Commissariat of Civilian Construction of RSFSR, Moscow*, 1946, pp. 2-83

This technical manual is designed to aid the construction engineer in building under winter conditions. There are 8 chapters including preparation for winter work, earth work or excavation, preparation and transportation of solutions and concrete, brick and stone work, concrete and steel work, roofing, laying floors, ceilings, and partitions under winter conditions and finishing work. Bibliography of 9 titles is given.

- (65) SOLOV'EV, S. P., "Permafrost in the Mountain Part of the Kabarda Palkariva", *Izvestia Geographical Society*, No. 3, pp. 364-368, Leningrad, 1937

This article describes the layer of permafrost discovered during a geological survey in the Tyrny-aus region of the northern Caucasus, some 90 kilometers west of the city of Nal'chik. Bibliography of 4 titles is given.

- (66) STEPANITSKAYA, N., "Permafrost in the U. S.S.R., Our Country", No. 10, 1938, pp. 55-56

This article discusses the origin and distribution of permafrost in the USSR. A map is given showing the limits of the permafrost area with other notes.

- (67) SUKHODOL'SKY, E. I., "Construction of Wooden Bridges in the Northern Districts of the Permafrost Area", *Moscow*, 1945

Material for this study was obtained from the 2 year expedition of the Committee for the Study of Permafrost which worked in the southwestern portion of the Taimyr Peninsula in the area of a narrow gauge railway. The author discusses the advantages of wooden bridges under local conditions as well as specific types of bridge construction. Bibliography of 12 titles is given.

- (68) SUMGIN, M. I. and PETROVSKY, A. A. "The Importance of Electrical Methods for the Study of Permafrost", *Trudy of Obruchev's Institute of Permafrostology*, Vol. V, *Moscow*, 1947, pp. 15-17

The author explains the many uses of the magnetic and electric methods is due to their comparative cheapness and rate of adaptability under a variety of conditions. Map is shown

giving the area in which geophysical methods have been applied. Bibliography of 6 titles is included.

- (69) SUMGIN, M. I., "Contribution to the Study of Permafrost in the Peat Mounds of the Kola Peninsula", Trudy of the Commission for the Study of Permafrost, Vol. III, Leningrad, 1934, pp. 107-115

This article is the partial result of the expedition of the Kola Peninsula in 1932 to study the influence of permafrost on the economy. Numerous peat mounds were investigated.

- (70) SUMGIN, M. I., "Permafrost", The Soviet Arctic, January 1936, pp. 93-97

This article points out the importance of the study of permafrost under the program of utilization of resources of the Soviet Arctic. The author states that permafrost is especially important in the study of Siberia.

- (71) SUMGIN, M. I., "The Future of the Study of Permafrost in the Yakut Republic", Trudy of the Committee for Permafrostology of the USSR Academy of Sciences, Vol. IX, pp. 5-27, 1940

This article describes the program for the study of permafrost in the Yakut Republic. The author sets up a number of theoretical problems as well as practical problems to be studied and solved. He states that a central laboratory should be set up in the Yakut Republic.

- (72) TOLSTIKHIN, N. I., "The Subterranean Waters of the Lithosphere", State Publishing House of Geological Literature of the Geological Commission of the Sovnarkom of the USSR, Moscow, 1941, 200 pp.

This article deals with the various phases of permafrost, groundwater, subterranean waters, and surface waters. Bibliography of 189 titles is given.

- (73) TSYTOVICH, N. A., "Some Peculiarities of Construction in the Permafrost in the Region of the City of Yakutsk", Trudy of the Committee for Permafrostology, Vol. IX, pp. 27-37, 1940

The author discusses the foundations of buildings in the city of Yakutsk, pointing out that the deformation of stone buildings in Yakutsk is very widespread, that brick buildings all show evidence of considerable cracking and settling, and that the preservation of permafrost would have prevented these deformations. He gives suggestions as to the methods of preserving permafrost and notes that small buildings could be erected on sandy, well-drained ground without special anti-permafrost measures.

- (74) TSYTOVICH, N. A., "The Problems of the Ground as Related to the Determination of the Depth of Foundations", Article in "Depth of Foundation Placement for Buildings with Few Stories in Conjunction with Seasonal Freezing of the Grounds", Institute of Permafrostology, Academy of Sciences, USSR, 1946, pp. 7-15

This article discusses the properties of water in the pores of the ground as related to the freezing of the ground. The article points

out there are 3 types of water according to present knowledge: bound water, oriented water, and free water. Bound water is characterized by the presence of enormous molecular pressure, has greater density than free water, etc. Oriented water is subject to molecular pressure of lesser intensity and only a portion of it freezes at the lower, of minus temperatures. The balance requires a much lower temperature before freezing. Experiments show that even at a temperature of  $-78^{\circ}\text{C}$ , a certain portion of the oriented water remains in the liquid state. Free water contained in the larger pores of the ground freezes at a temperature near  $0^{\circ}\text{C}$ . Capillary water freezes at  $-1$  to  $-4^{\circ}\text{C}$ . The author concludes by pointing out the necessity of further study of the freezing process of various types of ground in this region of the USSR.

- (75) TSYTOVICH, N. A. and SUMGIN, M. I., "The Principles of the Mechanics of Frozen Grounds", Academy of Sciences, Moscow, 1937, p. 432

This article by two of the Soviet's greatest specialists on permafrost consists of 10 chapters. Part I of the book deals with experiments and theory, and Part II with the practical application of the principles developed in Part I.

- (76) TSYTOVICH, N. A., "Study of the Elastic and Plastic Deformation of Frozen Grounds", Trudy of the Committee on Permafrost, Vol. X, Moscow, 1940, pp. 5-35

The author indicates the importance of the study of elastic deformation for stationary loads on the ground during construction. This is especially important in dealing with frozen ground and it becomes necessary to determine the relationship between these deformations and the minus temperature of the ground; specifically, at what temperatures the elastic and plastic deformations take place. Results of experiments by the permafrost laboratory of the Leningrad Engineering Institute of Communal Construction are given.

- (77) TSYTOVICH, N. A., "Certain Mechanical Properties of Permafrozen Grounds in the Yakut Region", Trudy of the Committee on Permafrost, Vol. X, Moscow, 1940, pp. 109-136

The author describes the results of field and laboratory investigations at several points in the Yakut region, including the town of Yakutsk. The author reaches the following conclusions: The degree of settling of the frozen ground at thaw under pressure depends upon the initial natural state of the ground especially on its porosity. The value of the coefficient of compressibility of frozen ground at thawing is a first degree function of the initial coefficient of porosity. The dust-silt sandy clay and argillaceous loams have the greatest degree of compressibility at thawing. The sands have the least. The described method of determining the coefficient of compressibility at thawing can be applied in

practice for construction purposes to enable the predetermination of possible settlement and the application of necessary counter measures.

- (78) TUMEL, V. F., "Contributions to the Study of Permafrost Conditions in the USSR", Academy of Sciences of the USSR, Trudy of Geographical Section, Vol. 37, Leningrad, 1946, pp. 124-131

This short article deals with the question of the origin of permafrost. The author compares the process of formation of glaciers with that of permanently frozen ground and indicates the difference between the two. Several genetically different types of permafrost conditions are described. There is a bibliography of 20 titles.

- (79) TUMEL, V. F., "The Sixth All Union Conference on Permafrostology", Vestnik of the USSR Academy of Sciences, Vol. 6, 1939, pp. 65-70

This article consists of a statement regarding the various reports by many specialists at the conference on permafrostology. Since 47 per cent of the total territory of the Soviet Union is subject to permafrost, the study of permafrost is considered of vital importance to the Soviet economy. The development of a station for permafrostology is being hindered by the insufficient number of trained workers; more instruction and more publication are needed in this field.

- (80) TUMEL, V. F., "Certain Geographical Results of Soviet Permafrostology", Izvestia of R. A. of S., Geographical Geological Series, Vol. X, No. 2, pp. 205-212, 1946

The history of the development of permafrostology was summarized in 1943 by Sumgin. The present article deals with the separate geographical aspects of permafrostology. References are made to the distribution of permafrost, temperature of permafrost, and suggested studies. A bibliography of 19 titles is given.

- (81) TUMEL, V. F., "Some Peculiarities of Behavior of Foundations under Occupied Buildings in the Northern Regions of Permafrost Distribution", Trudy of the Obruchev Institute of Permafrostology, Vol. I, pp. 5-26, 1946

The author cites several examples of building deformations resulting from changes in the permafrozen ground under their foundations and some practical measures which were utilized in an attempt to remedy the situation. The village of Dudinka and the city of Igarka had several problems in house foundations which were investigated. General climatic data of a given region do not give sufficient information for engineering purposes. Specific temperature data at the site are essential. Bibliography of 27 titles is included.

- (82) TUMEL, V. F., "The Igarka Experimental Underground Chamber in Permafrozen Ground", Publication of the Obruchev Institute of Permafrostology, 1945, pp. 3-80

The author gives a detailed account of the construction and characteristics of two underground chambers constructed at

the Igarka Permafrost Station. Temperatures and planning of such chambers are discussed at length. Bibliography of 12 titles is given.

- (83) TZIPLINKIN, E. I., "Permafrost and its Influence on Agriculture", Trudy of the Obruchev Institute of Permafrostology, Vol. IV, pp. 230-255, Moscow-Leningrad, 1944

The cultivation of plants under permafrost conditions is discussed at length. Methods of improving conditions such as the early deep winter plowing and the use of fertilizers are discussed. Bibliography of 47 Russian and 10 foreign references is given.

- (84) VITTENBURG, P. V., "The Temperature Changes and Underground Water in the Permafrost Zone on the Vaigach and Amderma Islands", Problems of the Arctic, No. 9, pp. 5-29, 1939

This technical pamphlet aims to give an answer to the following problems which are important for mining operations in the arctic, (1) depth of active layer, (2) lower limits of permafrost layer and depth to water, and (3) presence of mine waters in zone of permafrost and the state in which they are found -- solid or liquid. Bibliography of 10 titles is given.

- (85) YERMOLAEV, M., "Instruction for the Expeditionary Study of Fossil Ice as a Geographical Factor", The Arctic Institute, pp. 1-42, Leningrad, 1932

This pamphlet was issued by the All Union Arctic Institute for the study of fossil ice primarily during expeditions. The article has 10 illustrations and a bibliography of 140 titles, in Russian and foreign languages, containing literature dealing with regional descriptions of fossil ice, general works on the subject, petrography and paleontology.

- (86) YERMILOV, I. Y., "Permafrozen Ground in the Bogoslovsk Region of the Central Ural", Izvestia of the Geographical Society, Vol. 78, Parts 5-6, pp. 591-3, Leningrad, 1935

This article describes the occurrence of permafrost outside the limits of its basic distribution. The author cites four examples of the occurrence of permafrost in a bauxite mine, "The Red Hat", in the Central Ural.

- (87) ZHUKOV, V. F., "The Method of Determination of the Side Pressure on Shaft Linings in the Permafrost Region", Trudy of the Obruchev Institute of Permafrostology, Vol. 6, pp. 169-175, Moscow, 1944

This technical article deals with the methods of calculation of the stresses for shaft linings in the region of permafrost. The author discusses previous methods for calculating the pressure and suggests a new method. He believes his is more accurate since it takes into consideration the thawing of permafrost adjoining the outer walls of the lining.

- (88) ZHUKOV, V. F., "Cracking of the Ground Caused by Frost in the Permafrost Region", Trudy of the Obruchev Institute of Permafrostology, Vol. IV, pp. 226-229, Moscow-Leningrad, 1944

This article deals with the often encountered phenomena of cracking of the ground under freezing conditions. Frost cracks are due to the horizontal deformation of ground under the influence of freezing. With a sharp drop of temperature, the upper portion of the ground contracts. These cracks may reach a depth of 2.5 meters. Usually cracking takes place in the fall before the ground is protected by a layer of snow. The author suggests that damage to buildings can be prevented by keeping the buildings from being tightly frozen to the ground.

**10. BIBLIOGRAPHY OF RUSSIAN PUBLICATIONS DEALING WITH PERMAFROST AND RELATED SUBJECTS.** A list of the latest publications of the USSR on ice and snow, prepared by Professor B. P. Weinberg, Central Physical Observatory, Leningrad, USSR, is published by the National Research Council, Transactions of 1940, American Geophysical Union, Part II, pages 757-779. A general list, in English with some exceptions, of current publications on snow and ice is given on pages 750-756 in the same publication.

**11. SPECIAL REPORT, STRATEGIC ENGINEERING STUDY NO. 62.** "Permafrost or Permanently Frozen Ground and Related Engineering Problems", prepared by the U. S. Geological Survey for Military Intelligence Division, Office, Chief of Engineers, dated August 1945, contains a short bibliography on pages 225-230.

**12. LIST OF NEW RUSSIAN TECHNICAL PUBLICATIONS DEALING WITH PERMANENTLY FROZEN GROUND.** A bibliography has been received from the U. S. Geological Survey under the following title: "List of Some New Russian Technical Publications Dealing with Permanently Frozen Ground", by Miss Inna V. Poire, Geologist.

**13. RUSSIAN ARCTIC ENGINEERING DOCTRINE -- A BIBLIOGRAPHY.** The following bibliography was prepared by The Engineer School, The Engineer Center, Fort Belvoir, Virginia and is dated 29 August 1947: "Russian Arctic Engineering Doctrine, A Bibliography".

Part I consists of an introduction. The information contained in this bibliography was prepared from lists of Russian publications compiled by the U. S. Geological Survey and the Defense Research Board, Canadian Department of National Defense, Ottawa, Canada. The Engineer School is indebted to these agencies for making these lists available and for permitting their reproduction and distribution within the Corps of Engineers.

This bibliography represents only a part of the Russian works released in recent years. The value of the publications is limited since only a few complete English translations are available. In some instances, indicated in the bibliography, Russian volumes contain short English abstracts or summaries bound into the book, or have been abstracted in part by the Geological Survey or other holding agency.

Part II of this bibliography lists the titles obtained from the Geological Survey. Some of the texts are known to be in the Library of Congress, the Geological Survey Library, or the Smithsonian Library.

Part III lists the titles, obtained from the Canadian source, of Russian publications held by the Library of the Defense Research Board.

**14. BIBLIOGRAPHIES OF RUSSIAN LITERATURE. O.C.E.** The following bibliographies of Russian literature were received from the Office, Chief of Engineers:

- (1) GS 47/9 Committee on Geophysical Sciences of the Research and Development Board, "Explorations and Investigations Executed in 1944 by the Institute Merzlotovedeniia of the Academy of Science of the USSR", List No. 9, dated 12 April 1948

This is a list of 58 references dealing principally with permafrost and allied subjects.

- (2) GS 47/10 Committee on Geophysical Sciences of the Research and Development Board, "List of Some New Russian Technical Publications Dealing with Permanently Frozen Ground", List No. 10, dated 12 April 1948

This is a list of 50 references.

**15. SUMMARIES OF RUSSIAN ARTICLES. O.C.E.** The following summaries of various Russian articles were received from the Office, Chief of Engineers:

- (1) GS 63/1 Committee on the Geophysical Sciences of the Research and Development Board, "Works of the Institute for the Study of Frozen Soils of the Academy of Sciences of the USSR", from Russian periodical "Trudy Instituta Merzlotovedeniya imeni V. A. Obrucheva, Vol. V, 1947", edited by A. M. Chekotillo and subtitled "The Electrometry and Ondometry of Permafrost Strata"

Summaries of 8 articles on electrical methods for the study of permanently frozen ground are included.

- (2) GS 64/1 Committee on the Geophysical Sciences of the Research and Development Board, "Housing and Light Industrial Construction in Permafrost Regions", from Russian periodical "Trudy Instituta Merzlotovedeniya imeni V. A. Obrucheva", Vol. I, 1946, edited by A. Chekotillo, Acting Director of the Institute

Summaries of 4 articles on building foundations on permafrost are included.

- (3) KOBKO, P. P., SHISHKIN, N. I., MAREY, F. I., and IVANOVA, N. S., "Breakdown and Carrying Capacity of Ice", Physico-Technical Institute, Academy of Sciences, USSR, Leningrad, 26 June 1945

Presentation of data on the relation of breakdown load to the thickness of ice with a constant surface distribution of load. It was shown that, with ice from 0.15 to 40 cm thick, the relationship varies as the square of the thickness. Presentation of data on the relation of breakdown load to the area of distribution of load for ice with a thickness of 1.5 cm. It is shown that, with prolonged application of the loads, the carrying capacity of ice is determined by the combined total of elastic and plastic deformation.

- (4) IVANOV, K. Ye., KOBKO, P. P. and SHUL'MAN, A. R., "Deformation of an Ice Cover Under Moving Loads", Physico-Technical Institute, Academy of Sciences, USSR, Leningrad, 25 July 1945

The deformation of ice under the action of moving loads has been studied. It has been demonstrated that at speeds from 5 to 15 km/hr,

a movement of depression equal to the speed of movement of the load is observed. With speeds above 20 km/hr, wave vibrations which were formed spread far to the sides of the route. The formation of these waves was related to the generation the hydrodynamic waves produced by the movement of depression. A formula has been derived for the velocity of propagation of the ice waves as function of the coefficient of elasticity, the thickness of the ice cover, and the depth of the pond. The velocity of propagation of the ice waves ( $v = 35$  km/hr), their wave length ( $\lambda = 150$  meters), and the coefficient of elasticity of the ice cover ( $E = 44,000$  kg/sq cm), have been determined. The possibility of resonance, where speed of the moving loads equals the velocity of the propagation of the ice waves, has been demonstrated. In those instances, amplitudes large enough to cause the ice to break may develop. Sample rules for the movement of automobiles along a route are given. Bibliography of 11 articles is given.

- (5) KOBEKO, P. P., SHISHKIN, N. I., MAREY, F. I., and IVANOVA, N. S., "Plastic Deformation and Viscosity of Ice", Physico-Technical Institute, Academy of Sciences, USSR, Leningrad, 25 July 1945

A method was described of studying the plastic deformation of floating natural ice. Charts are given of elastic and plastic ice deformation. It was shown that the rate of plastic deformation is constant with a constant prolonged load. A method of measuring the viscosity of floating natural ice was developed. The viscosity of ice at 0 degrees C was determined. It was proved that plastic deformation even with small loads eventually leads to breakdown of the ice, if its temperature = 0 degrees C. Dangerous and safe values of breakdown pressures for long-time burdens on ice are determined. Bibliography of 8 titles is given.

- (6) Article from the USSR Engineering Permafrost Arctic Studies, February 1947, Zheleznodorozhnyy Transport, No. 2, "The Skovorodino Polar Station", translation prepared by Research and Development Board, Technical Intelligence Branch, GS 65/2

The Skovorodino Polar Station of the All-Union Scientific Research Institute of Railway Transportation is located in the far north, in the region of eternal frost. Its purpose is the systematic study of the geological, hydrogeological and geotechnical conditions of the eternal frost region with a view to installing and exploiting railway structures in such regions. Observations made on the Station throughout many years have determined that embedding of reinforced concrete foundations into the eternal frost layers, at a depth equaling half the height of the active layer, (which in Skovorodino amounts to 2-3 m) does not guarantee their stability. All foundations placed at such depth were subject to bulging in the winter, and to settling in the summer.

16. MECHANICS OF SOILS, BASES AND FOUNDATIONS. This office also has a translation of the Russian text on "Mechanics of Soils, Bases and Foundations", Part II, Second Revised Edition, Moscow, 1943, by A. V. Patalev and S. Ya. Bozhenkov.

Translation was prepared at the request of the Department of Research and Training Publications, The Engineer School, The Engineer Center, Fort Belvoir, Virginia, June 1947. This text was prepared for the Higher Technical Schools of Railroad Transportation. Chapter headings are as follows: Chapter I, Foundations under Permafrost Conditions; Chapter II, Constructing Foundations Subjected to Dynamic Influences; Chapter III, Reinforcing and Reconstructing Foundations.

#### IV Permafrost Bibliography

17. **BIBLIOGRAPHY OF ARTICLES IN ENGLISH.** A bibliography of articles on permafrost and allied subjects, prepared by the Permafrost Division, St. Paul District, follows this paragraph. These items have been carefully selected to furnish accurate, useful information for the study of permafrost. Many items are shown under several subject headings. This is particularly true of books covering a wide range of items.

##### a. **REPORTS PREPARED BY ST. PAUL DISTRICT AND CONTRACTORS**

(Restricted and not published unless otherwise noted)

**BELCHER, D. J.,** Research Engineer, "Report No. 4 on Aerial Photographic Reconnaissance Investigation. A Permafrost Study in the Territory of Alaska Conducted for St. Paul District Office, U. S. Engineer Department", 1 December 1945, Engineering Experiment Station, Purdue University for the St. Paul District, Corps of Engineers, U. S. Army

A report on field exploration of areas containing both permafrost and unfrozen ground and the study of observable details found on aerial photographs of these areas. The areas investigated were Northway, Tanacross, Big Delta, Galena, and Nome, Alaska.

**FROS\*, R. E. and HITTLE, JEAN E.,** "Summary and Statement of Technique on Aerial Photographic Reconnaissance Investigation of Frozen Soils in the Territory of Alaska", May 1947, Engineering Experiment Station, Purdue University for the St. Paul District, Corps of Engineers, U. S. Army

A summary and statement of the interpretation techniques for identification of permafrost from aerial photographs as obtained from data collected during two summers spent in Alaska.

**HITTLE, JEAN E.,** "Special Survey Report on a Landslide Condition on the Alaska Railway Between McKinley Park Station and Healy, Alaska", January 1948, Engineering Experiment Station, Purdue University for the St. Paul District, Corps of Engineers, U. S. Army

A report on a special survey made on a section of the Alaska Railroad which was in distress because of a landslide, as requested by the Alaskan Command through the Alaska District.

**PURDUE UNIVERSITY,** "Alaskan Photographs, Permafrost -- Airphoto Investigation", 1945, Purdue University, Engineering Experiment Station for the St. Paul District, Corps of Engineers, U. S. Army

This volume consists of a series of black and white photos taken by D. J. Belcher of Purdue University during a field trip to Alaska

in August and September 1945, in connection with the aerial photographic reconnaissance investigation under the contract held by Purdue University with the St. Paul District, Corps of Engineers. The depth to permafrost, various kinds of silt, sand and gravel formations, as well as vegetation and similar items pertinent to permafrost, are shown. The photos are taken along the Alaska Highway and include areas in the vicinities of Northway, Tanacross, Big Delta, Fairbanks, Cleary, Summit, Bettles, Galena, Nome, and Point Spencer.

STOECKELER, E. G., "Identification and Evaluation of Alaskan Vegetation from Airphotos with Reference to Soil, Moisture and Permafrost Conditions, A Preliminary Paper", June 1948, St. Paul District, Corps of Engineers, U. S. Army

The purpose of this paper is to familiarize the air-photo interpreter with (1) the basic natural influences which govern plant growth and distribution; (2) the value of vegetation as an indicator of soil texture, drainage and permafrost conditions; and (3) the description of air-photo patterns of the different cover types occurring in the permafrost zone in Alaska. This paper is written expressly for engineers and soils men having a limited knowledge of the botanical sciences and is not intended to be an ecological treatise.

SWARTZ, J. H. and SHEPARD, E. R., "Report on a Preliminary Investigation of the Possible Application of Geophysical Methods to Studies of Permafrost Problems in Alaska", 1946, Consultants, Office, Chief of Engineers for the St. Paul District, Corps of Engineers, U. S. Army

Report on an investigation to determine whether depths to permafrost and details of permafrost stratigraphy could be determined by geophysical measurements. Electrical resistivity measurements were made in the Northway, Fairbanks, and Galena areas, and a seismic station was measured near Northway.

UNIVERSITY OF MINNESOTA, "Laboratory Research for the Determination of the Thermal Properties of Soils, Quarterly Report", 1 April 1946, Engineering Experiment Station, University of Minnesota, for the St. Paul District, Corps of Engineers, U. S. Army

This report covers the activities carried on by the University of Minnesota, under contract, to determine under varying conditions of temperature, moisture, bulk density, and composition, the thermal properties of representative soils and organic material from Alaska. The specific tests included are thermal conductivity, specific heat, and diffusivity, as well as certain preliminary tests for identification, such as gradation, Atterberg limits, etc. This report reviews the conception of the idea of the thermal conductivity apparatus, the design, the construction, and the plan of testing, up to the date of the report.

UNIVERSITY OF MINNESOTA, "Laboratory Research for the Determination of the Thermal Properties of Soils, Semi-Annual Report", 1 October 1946, Engineering Experiment Station, University of Minnesota for the St. Paul District, Corps of Engineers, U. S. Army

This is a supplemental report to the quarterly report mentioned above. Thermal conductivity tests have been conducted on two soils, both sands. Several improvements have been made on the apparatus, and methods of placing the soils, running the tests, and making the calculations have been developed. The results are presented in tabular and graphical form. The results on one soil approximately check those determined by the Frost Effects Laboratory at Boston.

UNIVERSITY OF MINNESOTA, "Determination of Thermal Properties of Soils for Investigation of Airfield Construction in Arctic and Subarctic Regions", January 1948, Engineering Experiment Station, University of Minnesota for the St. Paul District, Corps of Engineers, U. S. Army (Published)

A report on a research program to determine, under varying conditions of temperature, moisture, bulk density, and composition, the thermal properties of representative soils and organic material from Alaska. Soils tested were typical materials from regions of permafrost. Mechanical analysis, plasticity, and compaction tests have been made on all of the soils. The program also included tests on precast insulating slabs prepared from materials used in the foundations of some of the experimental field installations in Alaska. The soil testing equipment used was designed and built in the Engineering Experiment Station.

UNIVERSITY OF MINNESOTA, "Final Report, Laboratory Research for the Determination of the Thermal Properties of Soils", September 1948, Engineering Experiment Station, University of Minnesota for the St. Paul District, Corps of Engineers, U. S. Army

This report presents the results of the investigation mentioned in the above report dated January 1948.

U. S. ARMY, "First Annual Report, Investigation of Airfield Construction in Arctic and Subarctic Regions", May 1946, St. Paul District, Corps of Engineers, U. S. Army

A report on an investigation composed of the following studies: (1) Site study of existing or proposed airfields; (2) Construction methods and equipment; (3) Meteorological data; (4) Laboratory research on thermal properties of soils; (5) Theoretical studies of heat flow in permafrost; (6) Library research; (7) Aerial photographic reconnaissance; (8) Geophysical exploration methods; and (9) Development of testing equipment for drilling and soil sampling work.

U. S. ARMY, "Supplement to First Annual Report, Investigation of Airfield Construction in Arctic and Subarctic Regions", October 1946, St. Paul District, Corps of Engineers, U. S. Army

A supplemental report to the First Annual Report mentioned above.

U. S. ARMY, "Interim Report on Arctic Construction Equipment", 12 July 1945, St. Paul District, Corps of Engineers, U. S. Army

A report on material collected on arctic construction equipment including opinions on airfield site selection, road and landing strip design, and discussions of methods of transporting equipment and supplies to a site, as well as statements pertaining to equipment and its use in the actual construction of airfields in the Arctic and Subarctic. Includes photographs and illustrations of equipment used in the Arctic and Subarctic.

U. S. ARMY, "Methods of Obtaining Core Samples in Permanently Frozen Ground", 23 October 1946, St. Paul District, Corps of Engineers, U. S. Army

A letter report on the experience of the Field Operations Branch, Permafrost Division of the St. Paul District in obtaining core samples from permanently frozen soil in Alaska. Deals primarily with the use of the Longyear Model UG 8-in. diamond core drill. Contains photographs of drilling operations and equipment.

U. S. ARMY, "First Annual Report, Arctic and Subarctic Drainage Investigations", September 1947, St. Paul District, Corps of Engineers, U. S. Army

A report on an investigation to determine design, construction and maintenance procedures suitable for the drainage of airfields located in arctic and subarctic areas subject to potential military operations.

U. S. ARMY, "Second Annual Report, Investigation of Airfield Construction in Arctic and Subarctic Regions", March 1947 (in 5 volumes), St. Paul District, Corps of Engineers, U. S. Army

The second annual report on this investigation includes the following: Main Report; Appendix A -- Photographs of Northway Airfield; Appendix B -- Construction Photographs of Fairbanks Research Area; Appendix C -- Photographs of Drilling Operations and Installation of Ground Temperature Equipment; Appendix D -- Report on Investigation of Foam Compounds for Cell Concrete Conducted by U. S. Waterways Experiment Station, Vicksburg, Miss.; Appendix E -- Comprehensive Program for the Investigation of Airfield Construction in Arctic and Subarctic Regions; Appendix F -- Laboratory Research for the Determination of the Thermal Properties of Soils by the Engineering Experiment Station, University of Minnesota; and Appendix G -- Report on Aerial Photographic Reconnaissance Investigation of Frozen Soils in the Territory of Alaska by the Engineering Experiment Station, Purdue University.

U. S. ARMY, "Permafrost Investigation, Military and Civilian Housing Areas, Ladd Field, Alaska", August 1947, St. Paul District, Corps of Engineers, U. S. Army

A report on the exploration and evaluation of the sites of proposed military and civilian housing at Ladd Field (Ladd Air Force Base), Alaska to determine the presence of permafrost and its influence on design.

U. S. ARMY, "Permafrost Investigation at Skull Cliff", July 1947, St. Paul District, Corps of Engineers, U. S. Army

A report on the excavation and footing construction with regard to permafrost at the Loran slave tower location at Skull Cliff near Barrow, Alaska, as requested by the Alaska District and the Navy made during the period 1 to 9 July 1947.

U. S. ARMY, "Final Report, Permafrost Field Investigation, Bettles Airfield, Alaska", May 1946, St. Paul District, Corps of Engineers, U. S. Army

A report on observations of construction and the construction history of the airfield at Bettles, Alaska.

U. S. ARMY, "Final Report, Permafrost Field Investigation, Galena Airfield, Alaska", 29 March 1946, St. Paul District, Corps of Engineers, U. S. Army

A report on the construction history of the airfield at Galena, Alaska and observations made by this office.

U. S. ARMY, "Pavement Crack Survey, 26 Mile Satellite Field, Near Fairbanks, Alaska", May 1947, St. Paul District, Corps of Engineers, U. S. Army

A report on an investigation of several typical asphalt pavement runway cracks made to ascertain the extent and nature of the cracks and to determine the probable causes of their formation.

U. S. ARMY, "Report on Permafrost Investigation for Mile 26, Satellite Field, Ladd Field, Alaska", June 1947, St. Paul District, Corps of Engineers, U. S. Army

A report on the exploration and evaluation of the site of the proposed P-36 airfield at Mile 26, Satellite Field, Ladd Field, Alaska to determine the presence of permafrost and its influence on the design, as requested by the Alaska District through the Office, Chief of Engineers.

U. S. ARMY, "Final Report, Permafrost Field Investigation, Nenana Airfield, Alaska", 19 April 1946, St. Paul District, Corps of Engineers, U. S. Army

A report on the construction history of the airfield at Nenana and observations made by this office.

U. S. ARMY, "Report on Foundation Investigation of Nome Post Office and Court House Building", April 1947, St. Paul District, Corps of Engineers, U. S. Army

A report on an investigation made by the St. Paul District for the Alaska District regarding the damage to the Nome Post Office due to subsidence and changes in frost conditions of the supporting ground.

U. S. ARMY, "First Interim Report, Permafrost Field Investigation, Northway Airfield, Alaska", 30 November 1945, St. Paul District, Corps of Engineers, U. S. Army

A report on an investigation at Northway Airfield to collect data on soil characteristics, ground temperatures, groundwater, foundation designs and other factors as they affect design and construction at this site, and to observe the effect of permafrost on the facilities of Northway Airfield.

U. S. ARMY, "Second Interim Report, Permafrost Field Investigation, Northway Airfield, Alaska", May 1946, St. Paul District, Corps of Engineers, U. S. Army

A summary of an investigation made at Northway Airfield to observe the condition and behavior of runways and structures constructed upon permafrost, to collect basic data, and to analyze these observations so that design formulas might be developed and suitable construction methods peculiar to regions of permafrost evolved.

U. S. ARMY, "Final Report, Observations During Construction of Project 'N', Alaska", June 1946, St. Paul District, Corps of Engineers, U. S. Army

A report on observations made during construction of an airfield and appurtenant facilities at Project "N", Point Spencer, Alaska, with special attention to permafrost conditions.

U. S. ARMY, "Report of Soils Analysis for Subgrade Materials at Site of Test of Insulating Properties of Beach Sand Foundations, Pt. Barrow, Alaska", June 1948, St. Paul District, Corps of Engineers, U. S. Army

A report on the soils analysis and evaluation of subgrade characteristics at the site of an experimental gravel fill in the proposed Fuel Storage Area, Barrow, Alaska.

U. S. ARMY, "Comprehensive Report, Investigation of Airfield Construction in Arctic and Subarctic Regions", January 1948, St. Paul District, Corps of Engineers, U. S. Army (in 8 volumes)

A comprehensive report on the permafrost investigation including the Main Report and following appendices: (1) Northway Airfield, Alaska; (2) Meteorological Data Studies; (3) Research Laboratory Investigation -- Determination of Thermal Properties of Soils; (4) Summary and Statement of Technique on Aerial Photographic Reconnaissance Investigation of Frozen Soils in the Territory of Alaska; (5) Library Research; (6) Design and Construction Studies -- Fairbanks Research Area; (7) Ground Temperature Equipment.

#### b. AIRFIELDS AND RUNWAYS

ALASKAN DEPARTMENT (U. S. Army, Alaska), Fort Richardson, Alaska, "Airfield Reconnaissance Survey, American River Site, Seward Peninsula, Alaska", January 1945, Secret

A report on a survey of the area "American River, Alaska, Airbase Site Project Location" to obtain general information for a proposed airfield site, in order that the air base could be planned, material quantities determined, housing areas established, as well as to locate the runways, taking into

consideration the glide angle of planes, possibility for fog accumulation, air drainage from the field, accessibility for transportation to and from the base to navigable water, and other items.

ALASKAN DEPARTMENT (U. S. Army, Alaska), "Airfield Reconnaissance Survey, Noxapaga-Imuruk Site, Seward Peninsula, Alaska", January 1945, Fort Richardson, Alaska, Secret

A report of the survey of the areas "Noxapaga-Imuruk" and "Collins-Hannum" of the Seward Peninsula for a proposed airfield site.

BESING, RAY D., Capt., CE and STARR, LEE B., 1st Lt., CE, "Operation Nanook-Airfield Construction Report No. 1", 1946, Engineer Aviation Battalion No. 1877, Thule Detachment, Geiger Field, Washington, Restricted  
A report on construction of two C-47 airstrips, one at Greenland and one at Melville Island.

BLACK, ROBERT F., "Permafrost Program, Progress Report No. 2, Permafrost Investigation at Point Spencer, Alaska", 1946, U. S. Geological Survey

Report on an investigation of the regional geologic aspects of permafrost as related to military engineering problems, particularly in regard to selection of airfield sites, so that ultimately, criteria can be established for the accurate forecast of the problems and conditions which will be encountered in permafrost areas of possible military interest that are inaccessible to ground reconnaissance.

BROADWELL, J. A., "How CAA Engineers Meet Construction Problems North of the Arctic Circle", Pacific Builder and Engineer, Vol. 51, No. 4, April 1945, pp. 55-56

An article on the construction of landing strips and radio navigational aides at Kotzebue and Shungnak, which describes transportation, labor, weather conditions, and utilities.

BUETOW, W. C., "Causes and Control of Damaging Frost Action in Shoulders and Subgrades", Proceedings, 8th Annual Asphalt Paving Conference, The Asphalt Association and Association of Asphalt Paving Technologists, pp. 146-151, 1929

General description of the action of frost boils and methods used in their eradication.

CALCIUM CHLORIDE ASSOCIATION NEWS, "Roads of Ice? What Next?", June 1948, p. 10

This is a brief reference to Project Habbakuk, the floating iceberg airdrome, one of the war's top secrets. The project was not completed until the end of the war and was never used. Frozen wood pulp and water became almost as strong as concrete when kept in that condition by refrigeration. The model of a floating airfield, invention of an Englishman named Geoffrey Pyke, was built on Patricia Lake near Jasper by Dr. C. D. Niven.

D'APPOLONIA, ELIO, "Foundations in Permafrost Regions", Tentative Report, 1 August 1944, Northwest Service Command Report

Part I deals with construction in permafrost regions and shows results of improper construction in a furnace room at Koidern Repeater Station, YT, and runway, garages, warehouses, and utilidor at Northway, Alaska. Points out in each case that construction was done incorrectly because of lack of knowledge that the transfer of heat causes melting of permafrost and settlement to failure of many structures; that construction with an air space using piling is a solution of the problem. Other chapters deal with wood pile foundations and runway design. An estimated cost of field research is shown as Part IV. A brief review indicates that the figures are too low.

D'APPOLONIA, ELIO, "Permanently Frozen Ground and Foundation Design, Part 2", Engineering Journal (Canada), Vol. 29, No. 1, pp. 7-12, January 1946

Reasons for failure of foundations for structures on permafrost and examples of designs to prevent melting of permafrost and causing excessive settlement of foundations.

ELIAS, M. M. and VOSBURGH, R. M., "Permafrost Program, Progress Report No. 1, Terrain and Permafrost in Galena Area", 1946, U. S. Geological Survey, Dept. of Interior

This report is a study of terrain and permafrost in a part of one of the large alluvial basins which characterize the topography in central Alaska. The report describes the general terrain of the basin, the relationship of ground and permafrost conditions to topography, suitability of the terrain units for construction, and criteria for interpreting the terrain from aerial photographs. The report presents the results of field investigation of two terraces near the Galena Air Base; the suitability of the two terraces for possible airfield sites is discussed.

ENGINEERING NEWS-RECORD, "Clearing Snow at a Northern Airbase", Vol. 135, No. 12, 20 Sept. 1945, pp. 107-111

Plenty of snow-handling equipment, operated by regularly assigned-enlisted personnel under direction of the post engineer, has kept the Presque Isle Airfield in northern Maine always ready for traffic. Trucks with one-way plows do most of the work with blowers used to boost the snow over the runway lights where the plows again push it to the edge of the safety strip. A plow with a powered vane in the wing is used to cut down the final bank left by the plows. Notes on snow handling at several other northern fields are appended.

ENGINEERING NEWS-RECORD, "The Saga of the Greenland Bases", Vol. 135, No. 10, 7 September 1944, pp. 96-100

This article describes the construction of some major bases, a few auxiliary airfields, and several weather stations in Greenland by American contractors and U. S. Army engineer troops. With regard to permafrost, the article is quoted as follows:

"Perhaps the most important lesson learned on construction operations in regions of permafrost is not to change the natural balance and flow of water, particularly in underground channels. In construction of runways, it is regular practice not to make cuts using fills only to attain a level surface. Fills are made largely with gravel from glacial moraine.....Preferred construction is to build above ground and to use thick gravel blankets below foundations to spread the load. An open space now is left below the building floor to permit air to circulate under the building so that heat is not transmitted to the ground. Double flooring is used and ceiling is added under the joists to keep floors warm in living quarters."

HENKEL, H. L., "Foundation Problems at the Bethel Airport", Pacific Builder and Engineer, Vol. 51, No. 5, May 1945, pp. 56-60

An article on the location and construction of the Bethel Airport, on the Kuskokwim River, on the southwestern mainland of Alaska.

HUBBARD, LEE D., "Construction Methods at Juneau", Pacific Builder and Engineer, Vol. 51, No. 4, April 1945, pp. 56-7

An article briefly describing the problems encountered such as flooded fill areas, continuous rainfall, and frozen borrow pits, in the construction of the CAA Airport at Juneau.

HUNT, RALPH W., Capt., CE, "Report of Operation Nanook", December 1946, Arctic Research Section, The Engineer School, Fort Belvoir, Va., Confidential

This report is a detailed account of Operation Nanook, an arctic expedition to obtain military and scientific information for use in planning future polar operations. Summarizes operations and conditions encountered, presents problems of special interest to the Corps of Engineers, and makes recommendations.

MCLEOD, NORMAN W., "Airport Runway Evaluation in Canada", Engineering Consultant, October 1947, Department of Transport, Ottawa. Published by Highway Research Board, National Research Council, Washington 25, D.C. Highway Research Board, Research Reports No. 4B, October 1947

This report outlines results of investigation of runways at a number of Canada's principal airports in 1945-46. Program of tests included: a pedological soil survey and preparation of a pedological soil map for each site; field moisture and density tests in place on base course and subgrade; securing large disturbed samples of base course and subgrade for physical and compaction tests; and undisturbed samples for CBR, triaxial compression, shear and consolidation tests, etc.

MCLEOD, NORMAN W., "Soil Science Applied to Subgrade and Base Course Design", Canadian Engineer, Vol. 77, No. 5, pp. 5-6, with discussion on pp. 52-54, August 1939

A review of published theories on the mechanics of frost heave constitute a portion of this article.

MORIARTY, C., "So You Think You Have Transportation Problems", Pacific Builder and Engineer, Vol. 51, No. 5, May 1945, pp. 52-55

An article by the Assistant General Manager, C. F. Lytle Company and Green Construction Company, on how Lytle and Green moved equipment, supplies and men to CAA project sites in the primitive Alaska interior despite some of world's toughest natural barriers of weather, water and terrain.

MULLER, DR. SIEMON W., "Construction of Runways and Buildings under Arctic or Subarctic Conditions", 21 November 1944, Office of Commanding General, Alaskan Division, ATC

A letter on the above subject to the Commanding General, Alaskan Division, ATC, which points out conclusions and recommendations as to the various methods of construction on permafrost. Also outlines a set of tools and the scope and plan of the study of permafrost for use by field men.

OCCIDENTAL PUBLISHING EDITORS, "Airport Reference -- 5th Annual Edition", Occidental Publishing Company, 1945-46 Edition

This book contains an airport equipment directory; airport planning, surfaces; lighting; buildings; communications; administration; airplane specifications; personnel directory.

ROADS AND STREETS, "Alaska Highway Flight Strips", June 1944, p. 80

Introduction expresses need for auxiliary strips. Construction and location problems similar to those faced on Alaskan Highway. Preliminary surveys, then final surveys after official approval. Route closely follows highway. Construction details discussed in brief. Clearing and grading done by Public Roads Administration, base course and wearing surface placed by contractor.

SCHERRER, FRED G., Captain, CE, and SCHIEWE, EUGENE C., Captain, CE, "Airfield Construction in Arctic and Subarctic Regions, Alaska", prepared under direction of Office, Air Engineer, Hqts., AAF, Washington, D.C., 30 November 1945

This unpublished manuscript contains a general description of the geography, meteorology, and ground conditions in Alaska with individual descriptions of the various airfields in Alaska at the time of the report -- 1945. Also contains chapters discussing methods of airfield design and construction, airfield site reconnaissance, transportation in the Arctic and Subarctic regions particularly by tractor train, winterization of engineer equipment, and conclusions and recommendations. It is well illustrated with many photographs. In general, this is an excellent review of airfield conditions in Alaska in 1945.

SEELEY, W. L., "How Rains, Cold Weather, Poor Soil Conditions Were Licked at Gustavus", Pacific Builder and Engineer, Vol. 51, No. 4, April 1945, pp. 48-54

A CAA airport built about 50 miles west of Juneau in southeastern

Alaska. Describes grading, draining and paving methods which successfully solved unusually tough problems encountered in building an isolated airport in Alaska's rain belt.

SEELEY, W. L., "General Factors Governing Design and Construction in Alaska", Pacific Builder and Engineer, Vol. 51, No. 5, May 1945, pp. 64, 67, 68, 70 and 72

An article giving a brief resume of climatic conditions, geology, construction and transportation in Alaska.

SHARP, SHAW AND DUNLAP, "Airport Engineering", 1944, John Wiley and Sons

A book on the engineering work involved in the planning and design of a modern air terminal.

STRATTON, J. H., "Military Airfields: A Symposium. Construction and Design Problems. Design of Drainage Facilities", Transactions, American Society of Civil Engineers, 1945, pp. 684, 764, 778, 781, 783

Brief statements on design of military airfield pavements for frost action.

THE ENGINEER SCHOOL, "Airfield Construction -- Airfield Drainage", Instructor's Manuscript, July 1943, 12 pp., Fort Belvoir, Va.

Discusses drainage problems, including subsurface, frost action and drainage structures.

THE ENGINEER SCHOOL, "Airfield Construction -- Surveying, Grading and Earthwork; Compaction and Bearing Power of Soils", Instructor's Manuscript, September 1943, Fort Belvoir, Va.

Discusses bearing ratio in connection with establishing thicknesses of base and flexible-type surface courses.

THE ENGINEER SCHOOL, "Airfield Construction -- Landing Mats, Construction Operations and Review of Course", Instructor's Manuscript, June 1943, Fort Belvoir, Va.

A course for Engineer School describing various types of steel landing mats.

THE ENGINEER SCHOOL, "Airfield Construction -- Airfield Location and Site Selection", Instructor's Manuscript, March 1943, Fort Belvoir, Va.

Discusses various considerations in the selection of sites for airfields.

THE ENGINEER SCHOOL, "Airfield Construction -- Soil Exploration and Classification", Instructor's Manuscript, August 1943, Fort Belvoir, Va.

Describes briefly the physical properties of soils which affect design and construction of airfields and methods of exploring.

U. S. GEOLOGICAL SURVEY, "Special Report, Strategic Engineering Study No. 47, Terrain Intelligence, Krasnoyarsk -- Welkal Air Route (Siberia, U.S.S.R.)", Intelligence Branch, Office, Chief of Engineers, January 1943, Confidential

A folio of maps, explanatory tables, and photographs which outline the principal terrain features of the following places and immediately adjacent areas: Krasnoyarsk, Ust-Kut, Kirensk, Tommot, Yakutsk, Oimyakon, Seimchan and Welkal. For each area, one or more maps and tables describe such subjects as topography, passability of terrain, anchorages, ports, landing beaches, possible airfield sites, kind and availability of construction materials, fuels, water supply, and special engineering problems connected with the permanently frozen ground.

WAR DEPARTMENT, "Investigation of Construction and Maintenance of Airdromes on Ice, 1946-1947, Report of Investigations", May 1947, Corps of Engineers, New England Division, Restricted

A report on a preliminary investigation of the feasibility of, and methods for, the design, construction and maintenance of airdromes on ice. Appendix A to this report is entitled "Aviation Uses of Ice by Vilhjalmur Stefansson" and Appendix B to this report is entitled "Translations". Appendix A considers aviation uses of lake and river ice, salt water ice, and inland or snow ice in an area farther north than 60° N. Latitude. Appendix B contains material translated from the Russian in the Stefansson Library.

WAR DEPARTMENT, "Flexible Pavement Tests, Marietta, Georgia, Construction, Testing and Data Report", 1 May 1945, Mississippi River Commission, U. S. Waterways Experiment Station, U. S. Army, Vicksburg, Mississippi, Restricted

A report on flexible pavement tests to determine subgrade deflections and pressures under various types of bases in common usage in this country and in certain theaters of operation for B-24 and B-29 wheel loads; with each plane empty, partially loaded, and fully loaded; and for standing and moving conditions both with plane motors dead and running.

WAR DEPARTMENT, "Surveys, Methods of Plotting, and Earthwork Computations for Airdromes", War Department Technical Bulletin TB ENG-18, 1 May 1944, Washington 25, D. C.

This bulletin supplements TM 5-255 with respect to survey procedure and earthwork computations for airdromes.

WAR DEPARTMENT, "Aviation Engineers", War Department Technical Manual TM 5-255, 15 April 1944, Restricted

This manual covers both tactical and technical phases of the training and operations of aviation engineers with special reference to their employment in theaters of operations. Designed for use as a reference handbook as well as text for training purposes.

WAR DEPARTMENT, "Report 881, Investigation of Airfield Construction in Arctic and Subarctic Regions", 28 October 1944, Office, Chief of Engineers, Confidential

The purpose of the investigations covered by this report was

the assembly of basic data pertinent to the reconnaissance, location, design, construction, and maintenance of airfields in arctic and subarctic regions, including runways and airfield installations. The investigation was confined to published literature, to the review of reports prepared by agencies familiar with construction practices in such regions, and to limited field examination of existing installations in Alaska.

WAR DEPARTMENT, "Airfield Pavement Design: Frost Conditions", Ad Interim Engineering Manual for War Department Construction, Pt. 12, Chapt. 4, July 1946, Corps of Engineers, Office, Chief of Engineers  
Conditions affecting frost action; heaving; insulating materials; base composition requirements; and protection of subgrade for flexible and rigid pavements with examples of design for frost action.

WAR DEPARTMENT, "Construction of Runways, Roads and Buildings on Permanently Frozen Ground", War Department Technical Bulletin TB 5-255-3, January 1945

Construction in arctic and subarctic regions usually requires methods and designs quite different from those used in temperate zones, especially on sites underlain by permanently frozen ground. It is necessary to cooperate with nature; not oppose her. This bulletin presents the best information now available on reconnaissance, design, construction, and maintenance for successful work in areas where permanently frozen ground exists. (This bulletin is being revised.)

WAR DEPARTMENT, "Summary of Frost Investigations", 4 December 1944, Frost Effects Laboratory, Boston District, Corps of Engineers  
Report describing the purpose and scope of the frost investigation program of the Boston District. The program includes review and analysis of airfield pavement failures, previous investigations; observation and testing of effect of frost action at a number of airfields during winter of 1944-45; performance of laboratory controlled tests to determine coefficients of heat transfer of various soils and the effect of compaction of soil upon frost action, etc.

WAR DEPARTMENT, "Frost Investigation, 1944-1945, Comprehensive Report", with 15 Appendices, February 1947, Corps of Engineers, New England Division

A comprehensive report covering laboratory work, review of previous investigations, and field studies at 15 airfields in the United States.

WAR DEPARTMENT, "Airfield Pavement Design: Construction of Airfields on Permanently Frozen Ground", Engineering Manual for War Department Construction, Part 12, Chapter 7, October 1946, Corps of Engineers, Office, Chief of Engineers

Design for conditions in permafrost regions, including design for freezing as well as thawing of foundations, for roads,

airfields, and structures.

WAR DEPARTMENT, "Frost Investigation, 1944-1945", July 1945, Corps of Engineers, Missouri River Division

Report of investigation to determine the development of frost action in subsurface pavement elements as affected by varying conditions of weather, soils, and groundwater. The airfields studied were: Sioux Falls Airfield; Fairmont Airfield; Great Bend Airfield; Garden City Airfield; and Pratt Airfield.

WAR DEPARTMENT, "Frost Investigation, 1944", January 1946, Corps of Engineers, Boston District

This is a report of the frost investigations performed at Dow Field, Bangor, Maine, during 1944 for the purpose of determining the influence of frost action on the subgrade soils beneath both rigid and flexible pavements at Dow Field upon the gross plane weight evaluation of these pavements. The testing program consisted of the excavation of test pits, explorations to determine base and subgrade soil profile under test areas, application to paved surfaces of controlled traffic during frost melting period, and the performance of pavement bearing tests during the frost melting period.

WAR DEPARTMENT, "Frost Investigation, First Interim Report, December 1944", Frost Effects Laboratory, Boston District, Corps of Engineers

This report presents the status of the frost investigation program and results of tests by the Boston District, the Missouri River Division, and Great Lakes Division to 1 December 1944.

WAR DEPARTMENT, "Frost Investigation, Second Interim Report, April 1945", Vols. I and II, Frost Effects Laboratory, Boston District, Corps of Engineers

This report presents the additional data, 1 December 1944 to 15 March 1945, secured since submission of the First Interim Report for each airfield selected for investigation in the Boston District, Missouri River Division, and Great Lakes Division.

WAR DEPARTMENT, "Frost Investigation, 1945-1946", June 1946, Corps of Engineers, Boston District

This is a report on studies of base course treatment to prevent frost action. This report presents (a) a summary of previous investigations performed by others, to study effect of admixtures on frost action; (b) the results of laboratory tests performed to determine suitability of various admixtures and combinations of admixtures; (c) results of laboratory tests to determine whether leaching of salts could be retarded or prevented by the addition of bituminous materials.

WAR DEPARTMENT, "Report on Frost Investigation, 1944-1945", April 1947, Corps of Engineers, New England Division

This report presents a summary of the studies, the observations and tests made, and the conclusions based upon these data including Part XII, Chapter 4, Ad Interim Engineering Manual. The work presented includes the data obtained in the investigations conducted in 1944 and 1945. The program for 1944-1945 consisted of the following phases: (1) A review and analysis of previous investigations of frost action; (2) Performance of laboratory controlled tests to determine coefficients of heat transfer of various soils; (3) Observation and testing of effect of frost action during winter 1943-1944 and 1944-1945 under paved and turfed airfield areas, and (4) The review and analysis of results of investigations performed.

WILSON, WALTER K. JR., Colonel, CE, "The Problem of Permafrost", The Military Engineer, April 1948, Vol. XL, No. 270, pp. 162-164

Describes study of permafrost started in 1945 by Corps of Engineers, St. Paul District. Field work in Alaska includes studies of airfields constructed during World War II, an experimental plot constructed near Fairbanks, weather and ground temperature data from various points, and development of methods for locating airfield sites from aerial photographs. Laboratory studies of thermal properties of soils were made at the University of Minnesota. Object of studies is to develop criteria for design and construction of airfields in arctic and subarctic regions.

#### c. ARCTIC AND SUBARCTIC

ALASKAN DEPARTMENT (U. S. Army, Alaska), "Reconnaissance to Determine Feasibility of Winter Operation of the Richardson Highway in Alaska", 20 December 1943, Fort Richardson, Alaska

An informal report on the feasibility of keeping the Richardson Highway open for freighting operations during the winter season, the problems to be encountered in such an undertaking, and the considerations involved, from an engineering standpoint.

ALASKAN DEPARTMENT (U. S. Army, Alaska), "Airfield Reconnaissance Survey, American River Site, Seward Peninsula, Alaska", January 1945, Fort Richardson, Alaska, Secret

A report on a survey of the area "American River, Alaska, Airbase Site Project Location" to obtain general information for a proposed airfield site in order that the air base could be planned, material quantities determined, housing areas established, as well as to locate runways, taking into consideration the glide angle of planes, possibility for fog accumulation, air drainage from the field, accessibility for transportation to and from the base to navigable water, etc.

ALASKAN DEPARTMENT (U. S. Army, Alaska), "Airfield Reconnaissance Survey, Noxapaga-Imuruk Site, Seward Peninsula, Alaska", January 1945, Fort Richardson, Alaska, Secret

A report of a survey of the areas "Noxapaga-Imuruk" and "Collins-Hannum" of the Seward Peninsula for a proposed airfield site.

ARCTIC, DESERT AND TROPIC BRANCH, AAF TACTICAL CENTER, "Handbook of Alaska, Informational Bulletin No. 18", April 1945, Published by Hqts., AAF Office of Asst. Chief of Staff, Training Aids Division  
General description of Alaska including topography, drainage, inhabitants, travel, climate, vegetation, animals, birds and fish. To be used in conjunction with the Pocket Guide to Alaska, prepared by the Special Service Division, ASF, the Arctic Manual (TM 1-240).

ATWOOD, W. W., "The Physiographic Provinces of North America", Ginn and Company, pp. 481-491

Brief description of the Pacific border of Alaska is presented. Coast ranges of southeast Alaska rising in general from 7,000-8,000 ft exhibit an old-age erosion surface. The Nutzotin and Alaska Ranges form an arc parallel to the Gulf of Alaska and extend out through Aleutians. They vary in height; the highest is Mt. McKinley. The Fairweather Range near Pacific exhibits snow-capped mountains, with very little soil mantle. St. Elias Range has a width of 150 miles and presents a nearly vertical wall on north side. The range appears to have been uplifted in Pleistocene time. Glaciers are prevalent throughout; glacial markings are also exhibited where ice was retreated.

BARNES, LYNN C., "Permafrost: A Challenge to Engineers", Military Engineer, Vol. 38, No. 243, January 1946, pp. 9-11

This article gives a brief discussion on permafrost regions, thermal regime, as well as discussion of the permafrost project assigned to the St. Paul District by the Corps of Engineers, D. A. Discusses briefly the investigations and tests, project objectives, and includes several photographs of natural soil and ice formations.

BESING, RAY D., Capt., CE and STARR, LEE B., 1st Lt., CE, "Operation Nanook-Airfield Construction Report No. 1", 1946, Engineer Aviation Battalion No. 1877, Thule Detachment, Geiger Field, Washington

A report on construction of two C-47 airstrips, one at Greenland and one at Melville Island.

BLACK, ROBERT F., "Permafrost Program, Progress Report No. 2, Permafrost Investigation at Point Spencer, Alaska", 1946, U. S. Geological Survey

Report on an investigation of the regional geologic aspects of permafrost as related to military engineering problems, particularly in regard to selection of airfield sites, so that ultimately, criteria can be established for the accurate forecast of the problems and conditions which will be encountered in permafrost areas of possible military interest that are inaccessible to ground reconnaissance. The immediate aim of the

investigation at Point Spencer was to determine the geologic and permafrost conditions with special emphasis on groundwater.

BODMAN, J. D., "Peculiarities of Aleutian Military Design", Civil Engineering, Vol. 15, September 1945, pp. 402-404

This article discusses difficulties involved in the design of military structures in the Aleutian Islands. One of the major factors affecting design is the fact that winds with an intensity of 100 miles per hour were common. Foundation conditions varied from solid rock to deep tundra and muck beds incapable of sustaining any appreciable load. No permafrost was encountered in the Aleutians. The article is illustrated with several photographs.

BROADWELL, J. A., "How CAA Engineers Meet Construction Problems North of the Arctic Circle", Pacific Builder and Engineer, Vol. 51, No. 4, April 1945, pp. 55-56

An article on jobs at Kotzebue and Shungnak which included landing strips and radio navigational aides.

BRYAN, KIRK, "Cryopedology -- The Study of Frozen Ground and Intensive Frost-Action with Suggestions on Nomenclature", American Journal of Science, Vol. 244, pp. 622-642, 1946

Cryopedology is suggested as a suitable name for the subsience concerned with the study, both theoretical and practical, of intensive frost-action and permanently frozen ground. Sixteen other terms are also introduced and defined. Of these, the important ones are pergelisol, permanently frozen ground, and mollisol, the overlying seasonally thawed ground in which intensive frost-action occurs. It is believed that these and the other suggested terms will facilitate discussion of the problems of the Arctic and of the ancient frost-action of periglacial areas.

BRYAN, KIRK, "The Study of Permanently Frozen Ground and Intensive Frost-Action", The Military Engineer, Vol. XL, No. 273, pp. 304-308

Cryopedology is suggested as a suitable name for the subsience concerned with the study, both theoretical and practical, of intensive frost-action and permanently frozen ground. Sixteen other terms are also introduced and defined. Of these, the important ones are pergelisol, permanently frozen ground, and mollisol, the overlying seasonally thawed ground in which intensive frost-action occurs. Comments on the suitability of Professor Bryan's terminology follow the main article.

BURICE, M. F., "Soil Temperature in the Matanuska Valley of Alaska", Transactions, American Geophysical Union, Part 1, p. 151

Relates to temperatures above freezing and for depths of 0-2-4-8 inches.

CAPPS, STEPHEN, "Geology of the Alaska Railroad Region", U. S. Geological Survey Bulletin No. 907, p. 207

Describes geology and geography of an area 140 mi wide and 450 mi long from north to south reaching from Gulf of Alaska northward into Yukon Basin. Includes illustrations and maps.

CAPPS, STEPHEN R., "The Chisana-White River District, Alaska", U. S. Geological Survey Bulletin No. 630, p. 130

Describes general geology and geography of this region with several illustrations and maps.

CAPPS, STEPHEN R., "Glaciation in Alaska", U. S. Geological Survey Professional Paper 170-A, p. 8

A discussion mainly of Pleistocene glaciation in Alaska.

CAPPS, STEPHEN R., "The Kantishna Region, Alaska", U. S. Geological Survey Bulletin 687, 1919

This bulletin covers an area bounded by the Alaska Range on the south, the Tanana River on the north, the Nenana River on the east, and the lower Kantishna River on the west; the area lies between the village of Nenana and Mt. McKinley. Field work was done in 1916. The geography and geology of this area were undertaken in 1916 because the Alaska Railroad was being built adjacent to this area, and it was anticipated that mining activity would be greatly increased. Coal as well as gold, silver and antimony was found.

CLARK, A. C., "The Alaska Highway -- Effect of Climate and Soils on Design", Civil Engineering, Vol. 13, No. 5, May 1943, pp. 209-212; Western Construction News, Vol. 18, March 1943, pp. 105-109

This paper explains the unusual soil and climatic conditions that were encountered during construction of the pioneer road for the Alaska Highway and their effect on design. It discusses the difficulties encountered in construction on permanently frozen ground or ice close to the surface immediately under a heavy insulating layer of moss or grasses; on layers of ice and frozen soil occurring at depths of 3 ft or more; and where an ice condition known as "glaciating" exists. Includes several photos.

COLBY, MERLE, "A Guide to Alaska", Federal Writers' Project, American Guide Series, 1944, 427 pp.

Here is all that a traveler needs to know about America's last frontier: how to get there; the main travel routes in Alaska; accommodations; climate; sport and recreation facilities; means of communication; approximate fare and living expenses; museums and libraries; what to see in McKinley Park and the four National Monuments; a vocabulary of terms frequently used in Alaska. Also contains the story of processes that have revolutionized the Territory; there is a chapter on Alaska's history from 1728 to yesterday; other chapters describe Alaska's developments in transportation and communication and its role in national defense, Alaska's rich natural resources, and the major towns and places of interest.

CRESSY, G. B., "Frozen Ground in Siberia", Journal of Geology, Vol. 47, No. 5, pp. 472-488, July-August 1939

A discussion of the types, depths, distribution of, and research history on permanently frozen ground in Siberia. Included also is discussion on Pleistocene glaciation and present climatic conditions in Siberia and causes of permanently frozen ground (permafrost).

DACHNOWSKI-STOKES, A. P., "Peat Resources in Alaska", Technical Bulletin No. 769, April 1941, U. S. Dept. of Agriculture, Washington, D.C.

Technical Bulletin 769 is based upon field work in 1939. It gives a general classification of most of the peat areas in Alaska. Among the conclusions stated is the following: "Among the qualifying factors that affect muskegs in the interior of Alaska are layers of volcanic ash, windblown silt, and a permanently frozen condition. The line of permafrost appears to have been rising periodically. Summer thawing ranges usually between 20 to 45 inches below the surface." It is estimated in this bulletin that about 50 million acres of Alaska may be classified as forest, approximately 100 million in tundra, and nearly 110 million in muskeg and grassy marshland. The term "muskeg" is of "Indian (Algonquin) origin denoting an area covered with sphagnum mosses and tussocks of sedges".

D'APPOLONIA, ELIO, "Permanently Frozen Ground and Foundation Design, Part 2", Engineering Journal (Canada), Vol. 29, No. 1, pp. 7-12, January 1946

Reasons for failure of foundations for structures on permafrost and examples of designs to prevent melting of permafrost and causing excessive settlement of foundations.

DEMENTIEV, A. I. and TUMEL, V. F., "Civil Engineering in Frozen Soil, U.S.S.R.", Canadian Geographical Journal, Vol. 32, No. 1, pp. 32-33, January 1946

A brief general description stating that progress has been made in combating drifting snow, mining, construction on permafrost (one statement that buildings are designed to prevent thawing, another that subsoil is warmed electrically using 300 to 1300 volts); and in the problem of drinking water in the eternally frozen areas (artesian wells through 700 ft of permafrost to depth of 1600 ft at Irkutsk). Permafrost covers 47 per cent of area of USSR.

DEPARTMENT OF TRANSPORT, "Meteorology of the Canadian Arctic", 1944, Air Services Branch, Meteorological Division, Canada

This manual contains a summary of the reports of meteorological observations which have been taken in the Canadian Arctic, together with an analysis of upper air conditions prevailing in this region. It is necessarily incomplete, chiefly because no long series of observations is available for this territory. Most of the observing stations are concentrated in the southeastern part of the Archipelago, leaving large areas of Canadian

territory within the Arctic Circle untouched. Tables and graphs are included showing monthly values of temperatures, precipitation, wind and fog at certain selected stations.

EAGER, W. L. and PRYOR, W. T., "Ice Formation on the Alaska Highway", Public Roads, Vol. 24, No. 3, January-March 1945, pp. 55-74

A treatise on the formation of surface ice. Includes discussion of factors associated with icing, and methods to prevent or reduce icing on new construction.

EAKIN, HENRY M., "The Iditarod-Ruby Region, Alaska", 1914, U. S. Geological Survey Bulletin 578

This volume is the third report based on work inspired by the discovery of gold in the Innoko district in 1906. In the province extending from Ruby, on the Yukon, to Iditarod, surveys seem to have established the fact that gold is associated in this district with two distinct series of rocks. The report shows that the bedrock sources of the placer gold of the district include the igneous intrusives and the Cretaceous sediments at or near their contacts with the igneous intrusives. Geologic conditions favorable to the occurrence of auriferous deposits are repeated in many places in this part of Alaska.

EAKIN, HENRY M., "The Yukon-Koyukuk Region, Alaska", U. S. Geological Survey Bulletin 631, 1916

Description of the process of solifluction (soil flow) or migration of detritus under thrust and heave of frost action under subarctic climatic conditions. Also includes visible features of frost heave mounds and the distribution of rock in mounds. Illustrated.

EARDLEY, A. J., "Unconsolidated Sediments and Topographic Features of the Lower Yukon Valley", Bulletin of the Geological Society of America, Vol. 49, pp. 303-342, February 1938

Report contains important material, geologic and topographic, on lower Yukon. Report locates gravel, sand, silts, and muck; their origin is a problem but some conclusions are stated. In general, it appears in the most part to be fluvial but the silt a combination of fluvial and aeolian. Regional topography appears as mature hills rising above lowlands. Much material, detailed, on local topography is presented. Valley shapes, stream patterns, stream re-entrants described. Gravels are high and low level, gravel cliffs (Palisades), pages 315-319. Silts are very widespread, complex bedding and origin, several types or groups (Palisades, delta sands at Cave-Off Cliffs and Anvik, Koyukuk-Anvik blue loam in lower Koyukuk and Yukon below Cave-Off Cliffs, muck of Palisades, Cave-Off Cliffs and upland placers. "Inlaid" series (complex) exist in meander belt below Cave-Off Cliffs). 13 pages on analysis, distribution, origin of silts. Brief coverage (4 pages) on late geologic history contained, very sketchy; mention of uplift, gently rejuvenated streams, etc. Mention of ice lenses, frozen ground. Many good photographs to illustrate features discussed in text and to

show general topography of region, many oblique air photographs. Tables used in silt identification, soil sizes and comparisons. Bibliography includes many U.S.G.S. references on Alaska.

EKBLAW, W. E., "The Importance of Nivation as an Erosive Factor and of Soil Flow as a Transporting Agency in Northern Greenland", Proceedings, National Academy of Sciences, Vol. 4, No. 9, pp. 288-293, 15 September 1918

A description of the process of nivation (the formation and melting of snow-ice) and its effect on the disintegration of rocks; the destruction of some land forms and the formation of others. A description of solifluction (soil flow) and its connection with nivation is also given.

ELIAS, M. M. and VOSBURGH, E. M., "Permafrost Program -- Progress Report No. 1 -- Terrain and Permafrost in Galena Area", 1946, U. S. Geological Survey, Dept. of Interior, Washington, D. C.

This report is a study of terrain and permafrost in a part of one of the large alluvial basins which characterize the topography in central Alaska. The report describes the general terrain of the basin, the relationship of ground and permafrost conditions to topography, suitability of the terrain units for construction, and criteria for interpreting the terrain from aerial photographs. The report presents the results of field investigation of two terraces near the Galena Air Base; the suitability of the two terraces for possible airfield sites is discussed.

ELLSWORTH, C. E. and DAVENPORT, R. W., "Surface Water Supply of the Yukon-Tanana Region, Alaska", Water Supply Paper 342.

Introduction includes scope of investigation. General features of area -- geology, geography, climate, vegetation (including map) covered. Measurement of stream flow, methods of unity, accuracy, tables, and description of main drainage areas included. Runoff data for various creeks in vicinity included in tables. Yukon River drainage basin, bounded by Pacific vents on south, Rockies on north, stream meanders towards west from Canada through Alaska for 2,000 miles. Above Eagle River, it flows swiftly in one channel, then near Fort Yukon it enters Yukon Flats (200 miles), then at junction of the Tanana it flows through Rampart Rapids (100 miles), then 800 miles of meandering river through a channel about 2 miles wide. Forty Mile River drainage basin, fan-shaped area 100 miles in largest diameter, rugged mountains, prominent feature is the terrace arrangements in valleys. Mission Creek, asymmetrical basin containing high gradients. Seventy Mile River, high gradient-benches are prevalent. Birch Creek, for 60 miles it is confined, maintains a fairly rapid flow, then for 100 miles it meanders in Yukon Flats about 10-20 miles from Yukon River. Beaver Creek, good gradient in foothills, then it meanders in Yukon Flats. Tanana River, an asymmetrical valley cut by glacier fed streams from Alaska Range, fairly broad valley. Tolovana River, is in a narrow valley (30 miles) at head, then

it opens abruptly into a wide valley (40 miles) at confluence of forks, then on leaving foothills it enters deep channel on alluvium, very low gradient, tortuous stream. Extensive tables of data taken, stream flow, etc. Streams taken up individually, some details included within reports on individual streams. Several maps included within report. Topographic maps showing gaging stations, also some sketch maps, i.e., distribution of vegetation in region covered. Also bibliography of Government papers on area covered. (About 50 papers listed.)

ENGINEERING NEWS-RECORD, "The Saga of the Greenland Bases", 7 September 1944, Vol. 133, No. 10 pp. 96 to 100

This article describes the construction of some major bases, a few auxiliary airfields, and several weather stations in Greenland by American contractors and U. S. Army engineer troops. With regard to permafrost, the article is quoted as follows: "Perhaps the most important lesson learned on construction operations in regions of permafrost is not to change the natural balance and flow of water, particularly in underground channels. In construction of runways, it is regular practice not to make cuts using fills only to attain a level surface. Fills are made largely with gravel from glacial moraine.....Preferred construction is to build above ground and to use thick gravel blankets below foundations to spread the load. An open space now is left below the building floor to permit air to circulate under the building so that heat is not transmitted to the ground. Double flooring is used and ceiling is added under the joists to keep floors warm in living quarters."

ENGINEERING NEWS-RECORD, "Clearing Snow at a Northern Airbase", Vol. 135, No. 12, 20 Sept. 1945, pp. 107-111

Plenty of snow-handling equipment, operated by regularly assigned enlisted personnel under direction of the post engineer has kept the Presque Isle Airfield in northern Maine always ready for traffic. Trucks with one-way plows do most of the work with blowers used to boost the snow over the runway lights where the plows again push it to the edge of the safety strip. A plow with a powered vane in the wing is used to cut down the final bank left by the plows. Notes on snow handling at several other northern fields are appended.

FEUSTEL, I. C., DUTILLY, A. and ANDERSON, M. S., "Properties of Soils from North American Arctic Regions", Soil Science, Vol. 48, No. 3, Sept. 1939, pp. 183-200

This paper includes the chemical and mechanical analyses, mineralogical composition and organic content determinations of soil samples collected at 15 widely scattered locations from Churchill north to the 76th parallel. A detailed description of 37 samples is given, including the geological classification of parent rocks, vegetation types, groundwater conditions and soil acidity. The influences of mechanical weathering forces, especially freezing, thawing and wind action, predominate in arctic

regions. The soils are characterized by the presence of unweathered rocks and rock fragments. Normal soil-forming processes of eluviation and illuviation are greatly retarded under the frigid climatic conditions. Tundra soil formations appear to be related to marsh types resulting from excessive moisture. Much of the area is overlaid with peat or muck. Organic residues do not readily decompose, but tend to accumulate on the surface as peat or peat-like materials. Most of the samples collected were acid and none were strongly alkaline. Of the 37 samples collected, only 3 of the soils contained 20 percent clay and nearly half had less than 5 percent. A large amount of the material was greater than 0.5 mm in diameter. The carbon-nitrogen ratios of mucks and peats are comparable to those occurring in Maine. Where lichens contribute to peaty accumulations, low carbon contents and low carbon-nitrogen ratios are expected. Reference is made to a shallow, clayey, alluvial soil found in a polygonic formation near Ft. Burwell, N.W.T. The authors state "the process of polygon formation is presumably directly related to a flooding or saturation of the soil with water followed by evaporation and resultant contraction of the material---a factor of particular importance relative to shrinkage behavior of this soil would seem to be the ratio silica to total bases." Very low ratio silica to total bases (3-5) is characteristic of arctic soils. Sodium content, on the other hand, is very high (approximately 1 percent). Exchangeable sodium in soil colloids tends to increase their capacity for swelling and shrinkage. The chief constituent of the soil colloids is hydrous mica, commonly called Ordovician bentonite. A bibliography of 20 references is included.

**FINNIE, RICHARD, "Canol", 1945, Taylor and Taylor, San Francisco**  
General pictorial history of Canol project. Numerous excellent pictures of construction, terrain, difficulties encountered. Brief text included to serve as introduction and explanation of pictures.

**HARDY, R. M., "Permanently Frozen Ground and Foundation Design, Part I", Engineering Journal (Canada), Vol. 29, No. 1, pp. 4-7, January 1946**  
Limited largely to discussion of permafrost but includes a review of theories of frost heave, and shows relationship between soil types and ice segregation in permafrost.

**HARRINGTON, G. L. and MERTIE, J. B. JR., "The Ruby-Kuskokwim Region of Alaska", U. S. Geological Survey Bulletin 754, 1924, 136 pp.**  
Bulletin 754 describes the geography, drainage, and geology, and other features of a mining region located south and west of Fairbanks, Alaska extending from Ruby on the Koyukuk River to the Kuskokwim River. The information was gathered from 1896 to 1920 and combines all available information up to the time of preparation of the report. It was prepared principally to assist mining operations in the Ruby-Kuskokwim region.

HARRINGTON, E. L., "Soil Temperatures in Saskatchewan", Soil Science, Vol. XXV

Thermometers were placed in the ground at depths from one to eight feet at the University of Saskatchewan at Saskatoon, Sask. It is pointed out that the temperature varies rapidly at the one foot level and that the lag in soil temperature below a two foot depth is marked. A comparison of the temperatures at Saskatchewan with those obtained by other observers in Kansas is made. It is pointed out that the maximum temperature at the 8 foot depth was reached in April and the first half of May. Permafrost is not discussed in this article. Graphs showing the results are included.

HAWKES, L., "Frost Action in Superficial Deposits, Iceland", Geological Magazine (London), Vol. 61, No. 725, pp. 509-513, November 1924

A description of several distinct types of effects of frost action in surface deposits in Iceland. Included are cracks in clays, knolls in grasslands, rings of stone, and formation of shallow hollows in gravels.

HEADQUARTERS, 925th ENGINEER AVIATION GROUP, "Roads and Highways in Alaska", Part I -- The Spring Thaw, 30 June 1948; Part II -- The Summer Season, September 1948, Fort Richardson, Alaska

Reconnaissance teams from the Headquarters, 925th Engineer Aviation Group, 807th Engineer Aviation Battalion and the 813th Engineer Aviation Battalion, began gathering information concerning conditions of roads and highways in Alaska during the spring thaw of 1948 on 1 April. Information was obtained from actual observations made during 5100 miles of traveling in Alaska. In general, conditions of the roads throughout Alaska were found to be very good. However, there were sections of the roads that were impassable at times. The worst piece of road was found on the Palmer Highway connecting Anchorage and Palmer. The second poorest stretch of road in Alaska was the road between Fairbanks and Eielson Air Force Base. The following highways were investigated: Palmer, Glenn, Richardson (Valdez to Gulkana), Richardson (Gulkana to Big Delta), Richardson (Big Delta to Fairbanks), Slana-Tok, Alaska and Edgerton Cutoff, Steese Highway and Elliott Highway. This report is illustrated with excellent pictures showing the methods used in taking care of icing and other work necessary in Alaska to maintain traffic.

HILL, E. M. M., Chief Engineer, "Memo Re Perpetually Frozen Subsoil Observations in the Vicinity of the Hudson Bay Railway", Canadian National Railways, Winnipeg, Manitoba, Canada, 29 March 1940

This article deals with perpetually frozen subsoil in the regions of the Province of Manitoba principally. It is pointed out that the southern boundary of permafrost exists somewhere between latitude  $54^{\circ}30'$  and  $55^{\circ}00'$  in Manitoba. Permafrost in this area may exist in the form of islands. North of  $55^{\circ}30'$  latitude, permafrost and tundra vegetation are continuous.

There is a table showing thickness of permafrost in various parts of Manitoba, Northwest Territory, and the Yukon Territory. A list of references regarding frost and soil temperatures in Canada is given.

HUNT, RALPH W., Capt., CE, "Report of Operation Nanook", Arctic Research Section, The Engineer School, Fort Belvoir, Va., December 1946

This report is a detailed account of Operation Nanook, an arctic expedition conducted by Navy Task Force 68 in which the Army, Coast Guard, Weather Bureau and other personnel participated to obtain military and scientific information for use in planning future polar operations. The report summarizes operations and conditions encountered, presents problems of special interest to the Corps of Engineers, and makes recommendations. It was submitted by an observer from The Engineer School, Fort Belvoir who accompanied the expedition. It covers the period from 15 July 1946 until 3 September 1946. Shore operations were conducted at Dundas Harbor on Devon Island in the eastern Canadian Archipelago and at North Star Bay in Wolstenholme Fjord, northwest Greenland, near the Danish village of Thule. During the expedition, the following operations were completed: Beach landing and ground operations by Marine Corps Detachment; establishment of arctic weather station by U. S. Weather Bureau; and construction of emergency landing strip near the weather station by Aviation Engineers. In this report, the term permafrost refers to the permanently frozen soil beneath an active layer of surface soil. The active layer varies in maximum depth from 30 to 36 in. on valley bottoms and from 8 to 12 in. on moss or tundra-covered terrain. The report is liberally illustrated with maps and photographs.

HUNT, RALPH W., "AGF Tests -- Frigid, Williwaw and Frost, Summary Report of Engineer Operations", 30 June 1947, Arctic Research Section, The Engineer School, The Engineer Center, Fort Belvoir, Va.

This is a summary report of engineer operations related to Army Ground Forces' tests Frigid, Williwaw, and Frost. Prepared by a representative of the Arctic Research Section of The Engineer School. The mission of the Task Forces was to obtain basic information necessary to develop equipment, techniques, tactical doctrine, and training methods necessary for efficient operation under winter conditions. The tests were conducted in areas with arctic, cold-wet, and heavy winter conditions from October 1946 to April 1947. There is no permafrost available in the area of Task Force Williwaw at Adak Island since the island is mostly solid rock. There is no permafrost in Camp McCoy near Sparta, Wisconsin. Other more detailed reports are to be prepared on these task force operations.

JAILLITE, W. MARKS, "Permafrost Research Area", The Military Engineer, September 1947, Vol. XXXIX, No. 263, pp. 375-379

This article describes construction by the Corps of Engineers,

D.A., of a research area near Fairbanks, Alaska for the purpose of studying the effect of permafrost (permanently frozen ground) on various types of foundations, using different kinds of insulation, piling, gravel fills, etc. Some of the difficulties of construction are described, including what happens when flowing artesian well is obtained when drilling for water through the frozen ground.

LEFFINGWELL, E. DeK., "Ground-Ice Wedges; The Dominant Form of Ground-Ice on the North Coast of Alaska", *Journal of Geology*, Vol. 23, No. 7, pp. 635-654, October-November 1915

A description of soil polygons and inclosing wedges of ground ice with an explanation of their origin and growth.

LEFFINGWELL, E. DeK., "The Canning River Region -- Northern Alaska", U. S. Geological Survey Professional Paper No. 109, pp. 179-243, 1919

An excellent early treatise on ground ice and permanently frozen ground. A discussion of diffusivity of frozen ground is included.

LEWIN, JOSEPH D., "Essentials of Foundation Design in Permafrost", *Public Works Magazine*, February 1948, pp. 28-30; *Public Works Magazine*, March 1948, Vol. 79, No. 3, pp. 27-30; and "Dams in Permafrost", *Public Works Magazine*, May 1948, pp. 22-23-32; *Public Works Magazine*, June 1948, pp. 33-34; *Public Works Magazine*, July 1948, pp. 57-58

This series of articles describes foundation conditions in areas such as Alaska and northern Canada where permanently frozen ground is encountered. Foundation design, including the effect of ice and other factors, is discussed. Design of a dam on a permanently frozen foundation is also discussed. References are made to several Russian articles on permafrost. Several illustrations are taken from publications of the Corps of Engineers, Department of the Army; a short bibliography is given.

MADDREN, A. G., "Smithsonian Exploration in Alaska in 1904", *Smithsonian Miscellaneous Collections*, Vol. 49, No. 1584, pp. 1-117, 1905

An important report of both general and specific nature. Much detailed material of value is contained in report including land forms, soil types, etc. Chapter headings are as follows: Introduction; Itinerary; Field of search; Glacial period and the mammoth; Horizon of mammoth in Alaska; Pliocene in Alaska; Gravels underlying Pleistocene silts mentioned; Brief outline of Pleistocene in Alaska; Depth of frost in circumpolar regions; Land ice of arctic and subarctic regions; Land ice and the mammoth; Conclusion -- mammoths died out due to change in climate -- climate never necessarily colder than at present -- deposits of ice tundra, etc., are products of Recent time. The appendix discusses the descriptions of ice beds of the Escholtz Bay in Kotzebue Sound and Kobuk River areas. There are many references scattered through report and many good photographs.

MAIERSPERGER, WALTER P., Major, Air Corps, Technical Observer, "Canadian Winter Exercise 'Musk-Ox'", October 1946, Air Materiel Command, Wright Field, Dayton, Ohio, Confidential

Exercise Musk-Ox was a movement of ground vehicles supported entirely by air. It has as its objective three broad subjects:

- (1) Air Force cooperation in the arctic; (2) Evaluation of over-snow vehicles under winter conditions; and (3) Certain technical and scientific research projects in the arctic.

MCLEOD, NORMAN W., Engineering Consultant, "Airport Runway Evaluation in Canada", Department of Transport, Ottawa, Canada; Highway Research Board, Research Reports No. 4B, October 1947

This report outlines results of investigation of runways at number of Canada's principal airports in 1945-46. Program of tests included: a pedological soil survey and preparation of a soil map for each site; field moisture and density tests in place on base course and subgrade; securing large disturbed samples of base course and subgrade for physical and compaction tests; and undisturbed samples for CBR, triaxial compression, shear and consolidation tests.

MEEKING, LUDWIG, "The Polar Regions: A Regional Geography", from "The Geography of the Polar Regions", American Geographical Society Special Publication No. 8, pp. 93-341, New York, 1928 (translated from the German language by W. L. G. Joerg).

The author, a professor of geography at the University of Münster, has worked with all branches of geography, especially polar geography, oceanography, and climatology. This book is divided into 2 main sections, namely, the Arctic and the Antarctic. More than three quarters of the book is devoted to the Arctic, principally because much more information of the North Polar Regions is available, and secondarily because of the wide variations of conditions encountered in the Arctic. The Antarctic is more uniform in all phases of geography than any other region on earth of similar size. The Arctic: A complete, brief chronological history of polar exploration describes the progress made by various explorers and discoverers, starting with Pytheas of Massilia in 325 B.C. to Wilkins in 1927. Much valuable information on climate, geology, geography, and the flora and fauna of the Arctic is contained in memoirs of the early explorers. In the bibliography of several hundred publications, particular emphasis is placed on expeditions made in the 18th and 19th centuries. The author divides the Arctic into three major geographical provinces: (1) Rock desert; (2) Ice desert; and (3) Tundra. Brief references are made to surficial markings common to the Arctic. These include polygonal cracks, stone circles, upraised clay areas, long solifluction stripes, and cryoconite holes. Detailed discussion of various subdivisions of the Arctic is made. The Antarctic: In 1501, islands in the Antarctic fringe were discovered, but not until 1772 did Cook define the limits of the Antarctic Continent. The author describes in detail the Antarctic and describes 11 individual

regions. The main significance of antarctica study is that the ice cap is probably a relic of the ice age and conditions existing there at the present time are probably similar to conditions which existed during the Pleistocene. It may be noted that because of the extremely rigorous climate, not one flowering plant occurs south of the Antarctic Circle. Grasses are not found south of 62°S. Land animals are nearly entirely lacking; however, sea animals are abundant, principally because of the abundance of diatoms.

**MERTIE, J. B., JR., "A Geologic Reconnaissance of the Dennison Fork District", U. S. Geological Survey Bulletin 827**

Location of area, previous investigations, limitations of this report, geography, drainage, relief, climate, vegetation, animal life settlements, all covered in introduction. Geology: sedimentary and igneous rock outcrops -- greenstone, granite, volcanic rocks (early, Recent), limestone, schist (Birch Creek), conglomerates described. Alluvial deposits: silt bluffs, possibly some glacial deposits, mentioned. Many benches occur, rejuvenation of Forty Mile River erosion to lower base level. Benches exist at various levels. Alluvial deposits are gravel, sand, silts, some to considerable thicknesses. Mineral resources discussed and classified. Coal-lignitic is primary mineral of importance.

**MERTIE, J. B., JR., "The Yukon-Tanana Region Alaska", U. S. Geological Survey Bulletin 872**

Initial surveys, extent of present survey (scale, detail, etc.) contained. Geography (details on drainage of area, pp. 11-32) covered. Settlements, population, transportation, climate, general information discussed. Geology outcrops of schist (fairly extensive) limestone, sandstones, shales, fossil studies are correlated in description. Unconsolidated deposits exist, not glacial, but much glacial outwash material reworked, smoothbed, water-worn. No direct glaciation exists but much material washed into valley -- boulder pavements, soil slumping, alluvial terraces, and deposits. Many deeply buried channels, cutting into older terraces and deposits. Streams seem to be in cycle of rejuvenation, i.e., islands in Yukon Flats are not growing but are being weathered and dissipated. Other material on igneous rocks, intrusives, geologic history and economic geology, placer deposits, hillside, valley, older alluvium, placers covered in remainder of report. References scattered through report. Geologic map included.

**MERTIE, J. B., JR., "The Chandalar-Sheenjek District, Alaska", U. S. Geological Survey Bulletin 810-B, 1929**

This bulletin discusses the geography and geology in connection with the mineral resources of the Chandalar-Sheenjek Rivers as well as streams in the vicinity. This area is located directly north of Fort Yukon on the Yukon River and extends up to the Brooks Range. The work was done in 1926 and 1927.

MERTIE, J. B., JR., "Mineral Deposits of the Ruby-Kuskokwim Region, Alaska", Geological Survey Bulletin 864-C, 1936

This bulletin discusses the geography and geology in connection with the mineral resources of the Ruby-Kuskokwim region in west-central Alaska between the Yukon and Kuskokwim Rivers.

MERTIE, J. B., JR., "Geology of the Eagle-Circle District, Alaska", Geological Survey Bulletin 816, Department of the Interior, 1930

This bulletin covers the area along the Yukon River between Circle and Eagle, from Circle upstream to the United States boundary. This bulletin discusses the geography and geology as well as climate and mining in an area which has been very active as a gold mining region since 1897. The work is based on field work by the writer in 1925 and includes references to statements from all prior geology work in this area. It is illustrated with many photographs and diagrams. A very brief reference to permafrost indicates that it has restricted the circulation of the deeper groundwater.

MOFFIT, FRED H., "Geology of the Nutzotin Mountains, Alaska", Geological Survey Bulletin 933-B, 1940, pp. 103-174

This paper deals primarily with the geology of the part of the Nutzotin Mountains extending southeastward from the Nabesna River to Beaver Creek and the boundary between Alaska and the Yukon Territory. This area includes the Nabesna gold mine, on White Mountains, and the Chisana placer-gold district near the head of the Chisana River, both of which have been important producers of gold. The field work represented on the geologic map was partly a revision of work previously done by the writer and others and partly an extension of mapping into areas hitherto unmapped.

MOFFIT, FRED H., and MERTIE, J. B., JR., "The Kotsina-Kuskulana District, Alaska", Geological Survey Bulletin 745, 1923

A geological survey to determine, examine and map in detail copper-bearing areas which give promise of yielding commercial ores. Survey was made in the Kotsina-Kuskulana district in the part of Alaska known as the Copper River region. It lies at the west end of Chitina Valley on the southwest slope of the Wrangell Mountains.

MOFFIT, F. H., "Geology of the Nome and Grand Central Quadrangles -- Alaska", U. S. Geological Survey Bulletin No. 553, pp. 53-54, 1913

Restatement of Tyrrell's description of "Crystosphenes or Buried Sheets of Ice in the Tundra of Northern America".

MOFFITT, F. H., "Geology of the Slana-Tok District, Alaska", U. S. Geological Survey Bulletin 904, p. 54

Discussion of area is covered (geographic) by previous work. Contains information on relief, drainage, transportation, vegetation. Geology of consolidated (schists, igneous rocks,

sedimentary) and unconsolidated deposits (glacial, alluvial, colluvial) is given. Extensive glacial deposits are in area. No preglacial deposits in evidence. Slana River shifts its channel over wide flood plain -- moraine still occupying most of valley to about 400-500 ft above river, kettle kame topography, ponds, lakes numerous; some kames relatively dry but moist soil in base gives luxuriant growth of grass. Morainal deposits occur elsewhere but not as conspicuously as in this valley. They occur especially where they are covered with trees. High gravels found at various levels to 2,000 ft above stream. Low benches occur on almost all streams. Description of placer and lake deposits follows geologic data and history. Geologic map of area included as well as some sketch maps and photographs of area.

MOFFIT, FRED H., "Geology of the Upper Tetling River District, Alaska", U. S. Department of the Interior, Geological Survey Bulletin 917-B, 1941

The term upper Tetling River district is here applied to a small part of the Alaska Range lying northeast of the Wrangell Mountains and extending from Suslota Pass to the Nabesna River. The rocks of the district are predominantly sedimentary, but include lava flows and tuffs, and areas of granitic intrusives. The district is strongly glaciated, and its unconsolidated deposits therefore include morainal material as well as the usual sand, silt, and gravel of the streams and lakes. Evidences of gold and molybdenum have been found.

MONTGOMERY, R. H., "Precise Levelling on the Alaska Highway", Transactions, American Geophysical Union, Vol. 29, No. 1, February 1948, Published by the National Research Council of the National Academy of Sciences, Washington, D. C.

Presents history of precise vertical control in Alaska and the Yukon; discusses particular problems encountered in bench mark construction and description when working in northern latitudes. Comments on evidence indicating regional earth movement.

MORIARTY, C., "So You Think You Have Transportation Problems", Pacific Builder and Engineer. Vol. 51, No. 5, May 1945, pp. 52-55

An article by the Assistant General Manager, C. F. Lytle Company and Green Construction Company, on how Lytle and Green moved equipment, supplies and men to CAA project sites in the primitive Alaska interior despite some of world's toughest natural barriers of weather, water and terrain.

MULLER, DR. SIMON WM., "Permanently Frozen Ground and Related Engineering Problems", Special Report, Strategic Engineering Study No. 62, Military Intelligence Division, Office, Chief of Engineers, August 1945

A comprehensive treatment of ice and permafrost. Of interest pertaining to normal frost action are: lag of ground temperatures behind air temperatures; fundamental principles governing formation of ice in soil; freezing temperatures of salt solutions; heat conductivity of soils; and swelling of ground during freezing.

MULLER, DR. SIEMON WM., "Construction of Runways and Buildings Under Arctic or Subarctic Conditions", Commanding General, Alaskan Division, ATC, 21 November 1944

A letter to the Commanding General, Alaskan Division, ATC, which points out conclusion and recommendations as to the various methods of construction of permafrost. Also outlines a set of tools and the scope and plan of the study of permafrost for use by field men.

NATIONAL RESEARCH COUNCIL OF CANADA, "Soil Temperatures in Canada -- Observations of Soil Temperatures", February 1937, Ottawa  
Observations were made from 1894 to 1900 at McGill University. Thermometers were placed at depths from 4 in. to 9 ft in sandy soil. Other observations were made at Guelph, Ontario from 1930 to 1932 and at the University of Saskatchewan from 1921 to 1923 and from 1929 to 1934. Some of these results have been taken from other papers. The effect of snow, rain and air temperatures on soil temperatures is discussed at length. The frost penetration and depth of water mains in various Canadian cities is given including Calgary, Edmonton, Moose Jaw, Regina, Winnipeg, Windsor, Brantford, Chatham, Ottawa. Permafrost in the Hudson Bay area and the Klondike region is stated to be over two hundred feet deep. At the maximum thaw, it is generally 5 in. to 10 ft in the summer time.

NIKIFOROFF, CONSTANTIN, "Perpetually Frozen Subsoil of Siberia", Soil Science, Vol. XXVI, No. 1, July 1928, pp. 61-79

This article discusses the location, thickness and temperature of permafrost, particularly in the vicinity of Yakutsk, Russia. The well of Shergeen at Yakutsk is stated to be 382 feet deep and the temperature at the bottom to be 3°C. A hypothesis as to the origin of permafrost is discussed. It is pointed out that the climatic conditions resulting in excess of cold may cause the permafrost. The other theory points out that permafrost may have been caused by glacial action. There is a discussion of soil blisters and ice caverns. It is pointed out that agriculture by the Yakuts has been successful in spite of the fact that the growing season is only one hundred days long. Of course, during the growing season, the sun shines from 21 to 22 hours per day. Dairying is the principal agricultural pursuit. It is pointed out that perpetually frozen subsoil in North America has received very little discussion in technical literature. A series of maps and graphs illustrating the author's dissertation are included.

NORDENSKJOLD, OTTO, "Polar Nature: A General Characterization", from "The Geography of the Polar Regions", American Geographical Society Special Publication No. 8, pp. 1-90, 1928, New York, translated by Dr. Ernst Anteus.

The presence of the polar regions of today enables scientists to visualize more clearly the conditions existing during the ice age. The climate, the ice covering and the sparse

vegetation are the 3 main factors which make polar nature what it is. With respect to climate, summer temperatures are far more important than winter temperatures on the characteristics of polar nature. Precipitation and wind velocity are of certain importance. The change of light conditions between summer and winter (daylight and darkness, in effect), the fauna and certain features of land forms are of minor importance. One of the major benefits which can be gained from knowledge obtained from polar research is to obtain a more accurate picture of "what happened" during the Pleistocene. The author, a geography professor at the University of Gothenburg (Sweden) has assembled climatological data and information of the flora and fauna gathered by numerous expeditions to various parts of the Arctic and Antarctic. A brief reference is made to soil forming agencies and soil formations, especially solifluction, polygonal soils, soil stripes and typical land forms occurring in polar regions. The author suggests that permanently frozen ground should be distinguished from layers of pure ground ice occurring directly beneath a thin vegetation mantle, found in Alaska, Siberia, and especially in the New Siberian Islands. A bibliography of 24 references, principally European Polar Expedition papers, is included.

**PORSLID, A. E., "Earth Mounds in Unglaciated Arctic Northwestern Alaska", Geographical Review, Vol. 28, No. 1, 1938**

Origin of mounds -- hypotheses covered are: (1) by hydraulic pressure, cracks caused on surface with possible steady seepage afterward, (2) so-called "local upheaval" on low marginal plains. Descriptions and photographs of "pingos" with cross section of one, also discussion of remnants and their cause included. Local upheaval is due to expansion of water as downward freezing progresses. Mention of cold storage vaults on "pingos" in Kotzebue region with discussion of their mode of origin. "Pingos" due to hydraulic pressure occur on slopes, to establish necessary head. "Pingos" of upheaval type on flat lying land.

**REGIONAL CONTROL OFFICE, "Weather Stations in Alaska and Western Canada", 15 February 1945, 16th Weather Region, AAF.**

This pamphlet contains a complete and accurate compilation of all information available at the time of publication on weather stations in Alaska and Central and Western Canada. The information is divided into three parts as follows: Part I -- List of Weather Stations in Alaska and Central and Western Canada; Part II -- Alphabetical List of Call Letters for Weather Stations in Alaska and Central and Western Canada; and Part III -- Numerical List of Index Numbers for Weather Stations in Alaska and Central and Western Canada.

**ROCHE, M. A. and MITCHELL, M. R. C., "Water Works and Sewerage in the Far North", Public Works Magazine, August 1948, pages 21-23**

A. Unusual Distribution System at Flin Flon, Manitoba, by M. A. Roche. Permanent frost exists here between 1 and 16 ft

below the surface. Water pumped through 13,000 ft of 20-in. woodstave pipe has not frozen in 18 years. Heating required on one occasion. Storage tanks and utilidors for distribution are steam heated. Distribution lines are in 4000 ft circuits in which water is circulated continuously. Steam is used to hold temperature at not less than 38° F.

B. Water and Sewerage at Sherridon, Manitoba, by M. R. C. Mitchell. Water mains and sewers are laid close together in trenches about 8 ft below the ground surface or together with steam pipes on the surface in wooden boxes packed with sawdust. The water mains are discharged into the dead ends of sewers to prevent freezing. Sewers laid in boxes are cast iron pipe and those buried in the ground are vitrified clay. The cost of heating the pipes in the boxes is quite high. Boxes inclosing pipes, in general, are large enough to permit a man to work inside without opening the box from the outside.

SCHERRER, FRED G., Capt., CE, and SCHIEWE, EUGENE C., Capt. CE, "Airfield Construction in Arctic and Subarctic Regions, Alaska", Prepared under direction of Office, Air Engineer, Hqts., AAF, Washington, DC, 30 November 1945

This unpublished manuscript contains a general description of the geography, meteorology, and ground conditions in Alaska with individual descriptions of the various airfields in Alaska at the time of the report -- 1945. Also contains chapters discussing methods of airfield design and construction, airfield site reconnaissance, transportation in the arctic and sub-arctic regions particularly by tractor train, winterization of engineer equipment, and conclusions and recommendations. It is well illustrated with many photographs. In general, this is an excellent review of airfield conditions in Alaska in 1945.

SCHMIDT, ROBERT W., "Frost and Permafrost, A Brief Survey of the Agencies and Literature Dealing with Frost and Permafrost", September 1948, Documentary Research Division, Air University Libraries, Air University, Maxwell Field, Alabama

A bibliography of 137 pages giving the agencies and literature dealing with frost and permafrost prepared for the use of Air University instructors and students.

SEELEY, W. L., "How Rains, Cold Weather, Poor Soil Conditions were Licked at Gustavus", Pacific Builder and Engineer, Vol. 51, No. 4, April 1945, pp. 48-54

An article on grading, drainage and paving methods which successfully solved unusually tough problems encountered in building an isolated airport in Alaska's rain belt.

SHARP, R. P., "Ground Ice Mounds in Tundra", Geographical Review, Vol. 32, No. 3, pp. 417-423, July 1942

Description of ground ice mounds in Wolf Creek region. Photographs and cross-sectional sketches included. Mode of origin discussed may be due to hydraulic pressure or of Porslid's

"upheaval" type, definitely not entombed ice because of surface indications of upheaval. Discussion of cycles observed in the development of ice mounds and their relation to the tundra topography produced -- knobs and depressions more or less masked by vegetation contained in report. Ground ice mounds should be considered along with solifluction, frost heaving and "Palsen" formation in the development of tundra topography.

SMITH, PHILIP S., "Areal Geology of Alaska", U. S. Dept. of the Interior, Geological Survey Professional Paper 192, 1939

A description of the general kinds and areal distribution of the major subdivisions of the different geologic formations that make up the visible rocky crust of the earth in Alaska.

SMITH, P. S. and MERTIE, J. B., JR., "Geology and Mineral Resources of Northwestern Alaska", U. S. Geological Survey Bulletin 815.

Introduction, past and present reports, including discussion of authors' trips, is included. Much covered on relief and drainage of (1) general features, (2) Koyukuk plateaus, (3) Brooks Range province, (4) Arctic plateaus, and (5) Arctic coastal plain. Description of climate, vegetation, wildlife, and population included. Geology broken down into periods for discussion; a very good table showing age and type of rocks in northwestern Alaska, Chandalar-Koyukuk region, Canning River region, Porcupine Valley region, and Eagle-Circle district contained in report. Very good chart, more exact locations within northwestern Alaska are found within the individual reports. Much limestone, some shales, sandstone, igneous intrusives. Unconsolidated deposits -- marine -- being formed along coast by action of waves and stream deposition. Ice shore features exist on beaches. Glacial -- (map showing extent of glaciation, page 243), outwash, moraines (lateral, recessional); some still exist. Fluvial -- much glacio-fluvial deposits, by far the largest of unconsolidated deposits, exist. Many benches, much outwash occur. Eolian -- dunes. Mention of ice in ground, ice wedges, some large masses, others vertical dikes. Description of igneous rocks, greenstones, basic intrusives and extrusives, granites, lavas with location noted included. Discussion of economic geology, petroleum, coal, gold placers, description of areas of importance in each category contained in report. Gold lodes, lead, iron, copper included, but are primarily of concern in bedrock studies. Good topographic and geologic reconnaissance maps of area. Many photos that are of value in description of text.

SPOFFORD, CHARLES M., "Engineering in the Far North", (Received from the Office, Chief of Engineers, 8 November 1948)

This article briefly discusses field work in the far North; type of clothing to be worn during summer and winter work in the field; temperatures; costs; permafrost; design; and sanitary engineering.

STEFANSSON, VILHJALMUR, "Arctic Mammal", 1944, MacMillan, New York

This manual was written for the Air Corps of the United States Army. It covers the following subjects: Historical background of Alaska, Physical geography, Climate and weather, Light in Polar regions, Animal life, Vegetation, Shelter, heat and light, Food and drink, Clothing and personal equipment, Health, accident and disease, Travel, Transportation, Hunting and fishing, and Mechanized transport.

TABER, STEPHEN, "Perennially Frozen Ground in Alaska: Its Origin and History", Bulletin of the Geological Society of America, Vol. 54, No. 1, 1943, pp. 1433-1548

Comprehensive treatise on permafrost. Principal subject matter includes: extent of permafrost; present climate in Alaska; vegetation, geological processes; Quaternary geology; perennially frozen ground; ground ice. Illustrated. Bibliography.

TABER, STEPHEN, "Some Problems of Road Construction and Maintenance in Alaska", Public Roads, Vol. 23, No. 9, pp. 247-251, July-August 1943

Origin, extent and description of perennially frozen ground and a review of the author's theory of segregation of water in the form of ice during freezing of soils.

TABER, STEPHEN, "Frost Heaving", The Journal of Geology, Vol. XXXVII, No. 5, July-August 1929

This paper describes a laboratory investigation of problems connected with frost heaving. The principles developed have applications in geology, plant physiology, and engineering. Pressure effects accompanying the freezing of soils are due to the growth of ice crystals and not change in volume. Pressure is developed in the direction of crystal growth, which is determined chiefly by the direction of cooling. Heaving is often greater than can be explained by expansion. It is due to the segregation of water as it freezes, more water being drawn up by molecular cohesion. The chief factors controlling segregation and excessive heaving are: size of soil particle, amount of water available, size and percentage of voids, and rate of cooling. Differential heaving is due chiefly to differences in soil texture and in the amount of available water, but differences in the kind and amount of soil cover are also factors.

TAYLOR, R. F., "Yield of Second-Growth Western Hemlock-Sitka Spruce Stands in Southeastern Alaska", Technical Bulletin No. 312, March 1934

A bulletin on the forest crops of southeastern Alaska. Gives the results of a study of growth and yield of even-aged, normally stocked, second-growth stands. The data for the study were obtained on 283 sample plots, varying in size from one tenth to one acre, laid out in representative young forests. Each plot contained from 150 to 300 trees.

**TAYLOR, RAYMOND F., "Pocket Guide to Alaska Trees", U. S. Dept. of Agriculture, Miscellaneous Publication No. 55.**

Three general types of vegetation occur -- spruce birch forest of interior; nonforested tundra of Arctic and Bering Sea slopes; dense hemlock spruce forests of coast. Coastal forests -- existing on Pacific side of Alaska Range from southeastern tip to Kodiak -- contains 70 percent hemlock, 25 percent spruce, 5 percent cedar, and others. Interior forests, existing in rivers and flats, contain spruce, birch bounded on south by Alaska Range, north and west by tundra and grasslands. Nonforested areas, grasslands, occur in Alaskan Peninsula, Aleutian Islands, south slopes of Alaska Range, tundra over vast section bordering Bering Sea and Arctic Ocean north of Brooks Range. Two pages used in brief identification of leaves followed by 27 pages of description of trees -- bark, wood, leaves, etc. and location. Pictures of leaves and cones included. Map accompanying report shows general location of trees -- scale 1:5,000,000.

**THE ENGINEER SCHOOL, "Bibliography of Arctic Literature with Glossary", Brochure No. 2, August 1948, The Engineer School, Fort Belvoir for the Chief of Engineers**

This bibliography was compiled at The Engineer School, Fort Belvoir at the request of the Chief of Engineers. Its purpose is to present a list of reports, letters, articles and books dealing with the subject of the Arctic and Subarctic. Section I gives a brief glossary of common arctic terms which have not yet been standardized or are at variance with the standard dictionaries. Words which are more or less standard arctic terms, such as eskimo, musk-ox and so on have not been considered. Section II lists the titles of those works which are available at most civilian libraries. Section III gives the titles of those works which are available through intelligence channels for authorized armed-force personnel only.

**THE ENGINEER SCHOOL, "Water Supply in Arctic, Subarctic, and Antarctic Regions", June 1948, The Engineer Center, Fort Belvoir, Va., Restricted**

This report presents the results of a study of arctic, subarctic, and antarctic water supply problems and methods. Its purpose is to furnish information needed to develop water supply methods at military bases and during field operations, and also to estimate future Army requirements. Much of the information was obtained from official reports of military operations by the armed forces of the U. S. and Canada and from Government publications of both nations. Various subjects covered are types of natural water resources; civilian water supply methods; military and naval water supply; recent developments in field water supply equipment, etc.

**TUCK, RALPH, "Origin of the Muck-Silt Deposits at Fairbanks, Alaska", Bulletin of the Geological Society of America, Vol. 51, pp. 1295-1310, 1940**

Introduction covers discussions of problems, description of district, mention of permanently frozen ground to depths of 200 ft, mentions location of frozen ground below muck deposits but in general not below silt deposits. Muck exists in valleys with the exception of Tanana River where gravel flats are exposed, but a lower muck horizon exists below present stream gravel. Much organic material, much ice. Muck dark when frozen, but turns light when thawed and oxidized, uniform size. Silt, from a few to 300 ft thick, with no definite upper limits, contains interbedded, ash layers, roughly horizontal uniform size. Origin -- silt has been assigned to lacustrine (not good because of lack of gradation) and sidehill creep and slides (this could hardly have happened in the production of such large quantities). Therefore, aeolian nature best adapted to situation of uniformity and quantity. Relation of silt to glaciation and rock floor of glaciers and indications of climate and vegetation from deposits of muck and silt discussed in report.

**TUCK, RALPH, "The Loess of the Matanuska Valley, Alaska", The Journal of Geology, Vol. XLVI, No. 4, May-June 1938**

Four objectives of quantitative study of sediments are outlined, each of which requires specially collected samples. The corresponding techniques of collection are here called engineering sampling, descriptive sampling, environmental sampling, and correlation sampling, according to the purpose of the samples. The steps in the systematic collection of samples for the first three purposes are outlined. Certain principles underlying efficient correlation sampling are considered. An example of the use of the sedimentation unit, showing how the boundaries of the individual units are determined, is given in detail. Six general steps for the determination of a sedimentation unit are given. Devices for obtaining the samples are described.

**UNIVERSITY OF ALASKA, "Earthquake Report for Interior of Alaska", 5 November 1947, College, Alaska, for Commanding Officer, US, AAB, Ladd Air Force Base, Alaska**

A summary of the present knowledge and opinion of members of the University of Alaska in the matter of earthquakes in the interior of Alaska.

**U. S. GEOLOGICAL SURVEY, "Alaska Volcano Investigations, Report No. 2: Progress of Investigations in 1946", written for the Corps of Engineers, Dept. of the Army**

In the interests of protecting military installations from destructive volcanism, the War Department, in October 1945, requested the Geological Survey to undertake a program of volcano research in the Aleutian arc. The general objective of the program is the collection and interpretation of geologic information which may be applicable to military operations in this area of active volcanism, with the ultimate aim of developing techniques for predicting the nature, location, and time of volcanic eruptions near

military establishments.

U. S. GEOLOGICAL SURVEY, "Terrain Intelligence, Revised Report, Strategic Engineering Study No. 27, Alaska", April 1943, written for Strategic Studies Unit, Intelligence Branch, Corps of Engineers, Confidential

This report consists of a folio of maps and explanatory tables outlining the principal geographic and related features of Alaska. They cover such subjects as terrain, climate, water supply, construction, transportation, geology and mineral resources.

U. S. GEOLOGICAL SURVEY, "Map of Alaska", Series E, 1946 Edition  
Political divisions, towns, cities, railroads, highways, and other pertinent information are shown. Scale is 1:2,500,000. Map was compiled by the Alaskan Branch of the United States Geological Survey.

U. S. GEOLOGICAL SURVEY, "Krasnoyarsk-Welkal Air Route, Siberia, USSR", Special Report, Strategic Engineering Study No. 47, January 1943, for Intelligence Branch, Office, Chief of Engineers, Confidential

A folio of maps, explanatory tables, and photographs which outline the principal terrain features of the following places and immediately adjacent areas: Krasnoyarsk, Ust-Kut, Kirensk, Tommot, Yakutsk, Olmyakon, Seimchan and Welkal. For each area, one or more maps and tables describe such subjects as topography, passability of terrain, anchorages, ports, landing beaches, possible airfield sites, kind and availability of construction materials, fuels, water supply, and special engineering problems connected with the permanently frozen ground.

WALLACE, ROBERT E., "Terrain Analysis in the Vicinity of Northway, Alaska with Special Reference to Permafrost", Permafrost Program Progress Report No. 3, July 1946, U. S. Dept. of Interior, Geological Survey

This report describes the permafrost conditions, ground types, construction considerations, and methods of identification of five major terrain divisions, their subdivisions, and their associated lakes in the vicinity of Northway in the Upper Tanana River basin of eastern Alaska. The five terrain divisions are river flood plains, sand dunes, lake-sediment terraces, alluvial fans, and bedrock areas. A major purpose of the investigation resulting in this report was to determine the relationship of permafrost to terrain types in the Northway area so that ultimately criteria can be established for the prediction of permafrost conditions in areas of possible military importance not accessible for ground investigation. Emphasis was placed on the use of aerial photographs in the analysis of terrain divisions.

WALLACE, ROBERT E., "Cave-In or Thermokarst Lakes in the Nabesna, Chisana, and Tanana River Valleys, Eastern Alaska", Permafrost Program Progress Report No. 4, 1946, U. S. Dept. of Interior, Geological Survey

Report on a study to develop criteria to be used in determining permafrost conditions by means of aerial reconnaissance. The present study of cave-in lakes in the Nabesna, Chisana, and

Tanana River valleys of eastern Alaska is part of an investigation of permafrost by the Geological Survey.

WAR DEPARTMENT, "Canadian Winter Exercise, Musk-Ox", U. S. Army, Washington, D. C., Confidential

This document contains the consolidated report of the six U. S. Army observers who participated in the Canadian Winter Exercise "Musk-Ox" which, during the period 15 February to 6 May 1946, traveled some 3200 miles from Churchill, Manitoba north through the arctic barren lands to Denmark Bay, westward along the sea-ice to Coppermine, NWT, across Great Bear Lake to the Mackenzie River at Fort Norman, NWT, southward through thawing conditions in deep snow and heavily wooded terrain to Fort Nelson, BC, thence by the Alcan Highway and rail to Edmonton, Alberta. The objects of the exercise were to study Army-Air Force cooperation; mobility of over-snow vehicles under winter conditions; methods of air supply, including possibility of establishing temporary landing strips; certain technical research projects in arctic warfare.

WAR DEPARTMENT, "Arctic Manual", Technical Manual TM 1-240, 17 January 1944

The viewpoint adopted in this manual is primarily that of Army personnel who will have to travel in the Arctic and live away from permanent posts. However, it also contains much information that is valuable to anyone stationed anywhere within the Arctic and Subarctic. It covers the following subjects: Character of the Arctic Country; Living in the Arctic.

WAR DEPARTMENT, "Principles of Cold Weather Clothing and Equipment", Technical Manual TM 10-275, 26 October 1944

The purpose of this manual is to insure proper use, care, and maintenance of cold-weather clothing and equipment. It deals with all important items of clothing and equipment used in cold climates and in the mountains.

WAR DEPARTMENT, "Construction of Runways, Roads and Buildings on Permanently Frozen Ground", War Department Technical Bulletin TB 5-235-3, January 1945

Construction in arctic and subarctic regions usually requires methods and designs quite different from those used in temperate zones, especially on sites underlain by permanently frozen ground. It is necessary to cooperate with nature; not oppose her. This bulletin represents the best information now available on reconnaissance, design, construction, and maintenance for successful work in areas where permanently frozen ground exists. (This manual is being revised.)

WAR DEPARTMENT, "Questions and Answers Pertaining to Cold-Weather Clothing", War Department Technical Bulletin TB QM 3, 28 January 1944

A bulletin of questions and answers concerning clothing and equipage necessary for cold climates.

WAR DEPARTMENT, "Operations in Snow and Extreme Cold", War Department Basic Field Manual, FM 70-15, November 1944

Military operations conducted under conditions of snow and extreme cold follow the same basic principles as do operations under other conditions. The differences lie in the tactical and logistical limitations imposed by the adverse climatic conditions and in the special equipment, training, and procedures necessary to overcome these limitations. The principles and doctrine described in this manual are applicable to operations conducted under conditions of snow and extreme cold in any type of terrain. They are not limited to operations in those portions of the world which are usually designated as "Alpine" or "Arctic".

WAR DEPARTMENT, "Report 881, Investigation of Airfield Construction in Arctic and Subarctic Regions", 28 October 1944, Office, Chief of Engineers, Confidential

The purpose of the investigations covered by this report was the assembly of basic data pertinent to the reconnaissance, location, design, construction, and maintenance of airfields in arctic and subarctic regions, including runways and airfield installations. The investigation was confined to published literature, to the review of reports prepared by agencies familiar with construction practices in such regions, and to limited field examination of existing installations in Alaska.

WICKERSHAM, JAMES, "A Bibliography of Alaskan Literature", College of Agriculture and School of Mines, University of Alaska, College, Alaska, 1927

This volume is supposed to contain a complete list of the titles of all printed books of history, travels, voyages, newspapers, periodicals, and public documents, in English, Russian, German, French, Spanish, etc., relating to, descriptive of, or published in Russian-America, now called Alaska, from 1724 to and including 1924. With the exception of the Introduction, it is a mere compilation of the titles of the books, etc. in which Alaska is described, or which were printed in Alaska, and are therefore in such intimate relation to the country as to be of value to the student who wishes to study the history of the Territory, or some of the various phases of the development of its material resources.

WILSON, WALTER K., JR., Colonel, CE, "The Problem of Permafrost", The Military Engineer, April 1948, Vol. XL, No. 270, pages 162-164

Describes study of permafrost started in 1945 by Corps of Engineers, St. Paul District. Field work in Alaska includes studies of airfields constructed during World War II, an experimental plot constructed near Fairbanks, weather and ground temperature data from various points, and development of methods for locating airfield sites from aerial photographs. Laboratory studies of thermal properties of soils were made at the University of Minnesota. Object of studies

is to develop criteria for design and construction of airfields in arctic and subarctic regions.

**d. BUILDINGS AND STRUCTURAL FOUNDATIONS**

ARCHIBALD, RAYMOND, "Peace River Bridge Builders Win Hard Race", Engineering News-Record, Vol. 131, No. 6, 5 August 1943, pp. 4 and 5  
Describes the location of the bridge and problems encountered during construction. Includes several photos.

BODMAN, J. D., "Peculiarities of Aleutian Military Design", Civil Engineering, Vol. 15, September 1945, pp. 402-404

This article discusses difficulties involved in the design of military structures in the Aleutian Islands. One of the major factors affecting design is the fact that winds with an intensity of 100 miles per hour were common. Foundation conditions varied from solid rock to deep tundra and muck beds incapable of sustaining any appreciable load. No permafrost was encountered in the Aleutians. The article is illustrated with several photographs.

D'APPOLONIA, ELIO, "Permanently Frozen Ground and Foundation Design, Part 2", Engineering Journal (Canada), Vol. 29, No. 1, pp. 7-12, January 1946

Reasons for failure of foundations for structures on permafrost and examples of designs to prevent melting of permafrost and causing excessive settlement of foundations.

D'APPOLONIA, ELIO, "Foundations in Permafrost Regions", Tentative Report, 1 August 1944, Northwest Service Command

Part I deals with construction in permafrost regions and shows the results of improper construction in a furnace room at the Koidern Repeater Station, Y.T., power, boiler house and utilidor, Northwest Territory, runway, garages, warehouses and utilidor at Northway, Alaska. Points out in each case that construction was done incorrectly because of lack of knowledge that the heat transfer caused melting of the permafrost and settlement to failure of many of the structures; that construction with an air space using piling is a solution of the problem. Other chapters deal with wood pile foundations in permafrost regions and runway design in arctic and subarctic regions. An estimated cost of field research is shown as Part IV. A brief review indicates that the figures are too low.

DOCKSTADER, E. A., "Effect of Freezing and Thawing of Soil Under Foundations of Cold Storage Warehouse", Proceedings, International Conference on Soil Mechanics and Foundation Engineering, Harvard University, Vol. 2, pp. 171-173, 22-26 June 1936

Factual data on depth of frost, height of heave due to heaving of foundation soil and settlement of foundation of a nine story cold storage building under controlled thawing.

ENGINEERING NEWS-RECORD, "The Saga of the Greenland Bases", 7 September 1944, Vol. 133, No. 10, pp. 96-100

This article describes the construction of some major bases, a few auxiliary airfields, and several weather stations in Greenland by American contractors and U. S. Army engineer troops. With regard to permafrost, the article is quoted as follows: "Perhaps the most important lesson learned on construction operations in regions of permafrost is not to change the natural balance and flow of water, particularly in underground channels. In construction of runways, it is regular practice not to make cuts using fills only to attain a level surface. Fills are made largely with gravel from glacial moraine.....Preferred construction is to build above ground and to use thick gravel blankets below foundations to spread the load. An open space now is left below the building floor to permit air to circulate under the building so that heat is not transmitted to the ground. Double flooring is used and ceiling is added under the joists to keep floors warm in living quarters."

HARDY, R. M., "Permanently Frozen Ground and Foundation Design, Part 1", Engineering Journal (Canada), Vol. 29, No. 1, 4-7 January 1946

Limited largely to discussion of permafrost but includes a review of theories of frost heave, and shows relationship between soil types and ice segregation in permafrost.

HENKEL, H. L., "Foundation Problems at the Bethel Airport", Pacific Builder and Engineer, Vol. 51, No. 5, May 1945, pp. 56-60

An article on how failure is changed to success when suitable site and borrow area are finally located for strategic base.

JAILLITE, W. MARKS, "Permafrost Research Area", The Military Engineer, September 1947, Vol. XXXIX, No. 263, pp. 375-379

This article describes construction by the Corps of Engineers, DA, of a research area near Fairbanks, Alaska for the purpose of studying the effect of permafrost (permanently frozen ground) on various types of foundations, using different kinds of insulation, piling, gravel fills, etc. Some of the difficulties of construction are described, including what happens when flowing artesian well is obtained when drilling for water through the frozen ground.

LEWIN, JOSEPH D., "Essentials of Foundation Design in Permafrost", -- Two articles: Public Works Magazine, March 1948, Vol. 79, No. 3 and Public Works Magazine, Feb. 1948, pp. 28-30; "Dams in Permafrost", -- Three articles: Public Works Magazines for May, June and July 1948.

This series of articles describes foundation conditions in areas such as Alaska and northern Canada where permanently frozen ground is encountered. Foundation design, including the effect of ice and other factors is discussed. Design of a dam on a permanently frozen foundation is also discussed. References are made to several Russian articles on permafrost.

Several illustrations are taken from publications of the Corps of Engineers, Department of the Army. A short bibliography is given.

LINDE, S. F., "The Freezing of the Foundation Soil Under Cold Storage Buildings", *Warme u. Kältetechnik*, 1942, 44 (2) 17-23; (3) 34-8; *Building Science Abstracts*, Vol. 16 (New Ser.), No. 3, Abstract No. 198, p. 41, March 1943

Soil temperatures correlated with vertical movements of a cold storage warehouse and conclusions concerning design of foundations for cold storage warehouses.

MULLER, S. W., "Permafrost or Permanently Frozen Ground and Related Engineering Problems", 1945, U. S. Geological Survey, Special Report, Strategic Engineering Study No. 62, prepared for Military Intelligence Division, Office, Chief of Engineers, U. S. Army. Second printing: Ann Arbor, Michigan -- J. W. Edwards, Inc., 1947, 231 pp. Reprint.

A comprehensive treatment of ice and permafrost. Of interest pertaining to normal frost action are: lag of ground temperatures behind air temperatures; fundamental principles governing formation of ice in soil; freezing temperatures of salt solutions; heat conductivity of soils; and swelling of ground during freezing.

MULLER, DR. SIEMON W., "Construction of Runways and Buildings Under Arctic or Subarctic Conditions", Commanding General, Alaskan Division, ATC.

A letter to the Commanding General, Alaskan Division, ATC, which points out conclusions and recommendations as to the various methods of construction on permafrost. Also outlines a set of tools and the scope and plan of the study of permafrost for use by field men.

PARADIS, ALPHONSE, "Foundations and Protection Against Frost Heaving", *The Canadian Engineer*, Vol. 67, October 1934, pp. 21-24

A description of field experiments involving the use of 'sand cushions' up to 12 in. in depth and, a discussion of the use of 'sand cushions' as bases under roads to prevent frost heaving. The use of sand is advocated because "...it has a much lower thermal conductivity than any other road building material".

PLUMMER, F. L. and DORE, S. M., "Soil Mechanics and Foundations", Pitman Publishing Corp., 1949

Heaving of highway slabs, ice segregation, effect of texture, effect of colloidal material, movement of water to form ice crystals, effect of consolidation, effect of water table level, effect of surface load, unfavorable subgrade conditions, thawing of frozen soil, frost in foundations, typical frost heaving example, and prevention of frost heaving.

POPULAR SCIENCE MONTHLY, "Revolt of the Earth: Permafrost Tests Ingenuity of Arctic Builders", *Popular Science Monthly*, Vol. 149, pp. 126-9,

November 1946

Difficulties of building in permafrost regions.

WAR DEPARTMENT, "Piles and Pile Driving", Technical Bulletin TB ENG 32, 3 July 1944

This bulletin contains information on standard and expedient pile-driving equipment; preparation and driving of piles, and load capacity of piles and required pile lengths. Both hasty construction of temporary structures and deliberate construction of carefully planned and well designed structures are discussed.

WAR DEPARTMENT, "Construction of Runways, Roads and Buildings on Permanently Frozen Ground", War Department Technical Bulletin TP 5-255-3, January 1945

This bulletin presents the best information now available on reconnaissance, design, construction, and maintenance for successful work in areas where permanently frozen ground exists. (This bulletin is being revised.)

#### e. CONSTRUCTION MATERIALS

AMERICAN CONCRETE INSTITUTE, "Recommended Practice for Winter Concreting Methods (ACI 604-48)", Journal of the American Concrete Institute, Vol. 20, No. 1, September 1948 (ACI Proceedings Vol. 45), p. 1-18

This ACI Standard establishes standard methods of cold weather concreting for thin sections and mass concrete. Heating of materials, accelerators and anti-freezes, curing and temperature records during curing, subgrade (or base) preparation, protective coverings during curing, and form removal are discussed for both types of job, and preferred methods are indicated. An appendix entry outlines objectives of the special winter methods with background material which indicates the "why" of some of the recommended practices. Charts in the appendix indicate effect of curing temperature on concrete strength, and a list of 135 selected references to periodical literature on winter concreting methods is included.

COLLINS, A. R., "The Destruction of Concrete by Frost", Journal of the Institution of Civil Engineers (London), Vol. 23, No. 1, pp. 29-41, November 1944; Highway Research Abstracts, No. 116, pp. 5-7, January 1945; also in American Concrete Institute Journal, Vol. 16, June 1945, pp. 726-27, and in Concrete and Construction Engineering, Vol. 39, April 1944, pp. 100-107

Measurement of total volume of water in concrete by the dilatometer method; determination of volume change-temperature relationships on freezing; and discussion of the mechanism of failure of concrete during freezing as compared to soils.

CONNERMAN, H. F., "Tests of Concretes Containing Air-Entraining

Portland Cements, or Air-Entraining Materials Added to Batch of Mixer; Vinsol Resins and Other Materials", American Concrete Institute Journal, Vol. 15, June 1944, pp. 477-507

HANSON, W. C., "Influence of Sands, Cements and Manipulation upon the Resistance of Concrete to Freezing and Thawing", Journal of the American Concrete Institute, Vol. 14, No. 2, November 1942, pp. 105-123

HAZEN, ALLEN, "Some Physical Properties of Sands and Gravels", 24th Annual Report, Massachusetts State Board of Health, 1893

JOURNAL OF THE SOCIETY OF CHEMICAL INDUSTRY, BRITISH, "Problems of Porous Bodies and Their Behavior as Building Materials", Vol. 53, 28 December 1934, pp. 379T to 402T

MCADAM, D. J. JR., et al, "Technical Cohesive Strength of Some Steels and Light Alloys at Low Temperatures", American Society for Testing Materials, Proceedings, Vol. 44, 1944, pp. 593-624

MCADAM, D. J. JR., and MEBS, R. W., "Technical Cohesive Strength and Other Mechanical Properties of Metals at Low Temperatures", American Society for Testing Materials, Proceedings, Vol. 43, 1943, pp. 661-703; 704-706

MCCOY, W. J., "Obtaining Concrete Resistance to Freezing and Thawing by Adding Vinsol Resin at the Mixer", Roads and Bridges, Vol. 82, July 1944, pp. 48-49

MEISSNER, H. S., "Laboratory Freezing and Thawing Tests on Concrete Containing Various Air-Entraining Agents", American Concrete Institute Journal, Vol. 15, June 1944, pp. 517-522

MEYER, E. V., "Cell Concrete", 25 Years of Civil Engineering, Christiani and Nielsen, New York, N.Y., 1904-1929, pp. 139-153

Cell concrete insulation -- a discussion of the manufacture and use of cell concrete, using the foam compound developed by Christiani and Nielsen.

NORGAARD, H., "Long-Distance Heating Systems Insulated with Cell Concrete", 25 Years of Civil Engineering, Christiani and Nielsen, 1904-1929, pp. 154 and 157

PEARCE, E. E., "Methods and Cost of Thawing Frozen Gravel by Means of Cold Water", Engineering and Contracting, Vol. 57, 15 February 1922, pp. 157-8

POWERS, T. C., "Working Hypothesis for Further Studies of Frost Resistance of Concrete", American Concrete Institute Journal, Vol. 16, February 1945, pp. 245-272

ROADS AND BRIDGES, "Effect of Freezing and Thawing on Concrete Pavements", Vol. 84, January 1946, pp. 65-68

ROWLEY, F. B., et al, "Thermal Conductivity of Insulating Materials at Low Mean Temperatures", Refrigerating Engineering, Vol. 50, December 1945, pp. 541-44

STONE, J. F., "Insulation for Low Temperatures", Engineering Refrigerating, Vol. 46, July 1943, pp. 31-37

U. S. DEPT. OF INTERIOR, "Concrete Manual", Bureau of Reclamation, Denver, Colorado, October 1942

U. S. DEPT. OF INTERIOR, "Thermal Properties of Concrete, Boulder Canyon Project, Final Reports, Part VII -- Cement and Concrete Investigations, Bulletin I", Bureau of Reclamation, Denver, Colorado, 1940, p. 154.

WALKER, S., "Freezing and Thawing Tests of Concrete Made with Different Aggregates", American Concrete Institute Journal, Vol. 15, June 1944, pp. 573-77

WOODS, W. H., "Resistance of Concrete to Freezing and Thawing", Concrete, Vol. 48, No. 5, May 1940, p. 8.

#### f. DRAINAGE

ELLSWORTH, C. E. and DAVENPORT, R. W., "Surface Water Supply of the Yukon-Tanana Region, Alaska", Water Supply Paper 342

Introduction includes scope of investigation. General features of area -- geology, geography, climate, vegetation (including map) covered. Measurement of stream flow, methods of unity, accuracy, tables, and description of main drainage areas included. Runoff data for various creeks in vicinity included in tables. Yukon River drainage basin -- bounded by Pacific vents on south, Rockies on north, stream meanders towards west from Canada through Alaska for 2,000 miles. Above Eagle River, it flows swiftly in one channel, then near Fort Yukon it enters Yukon Flats (200 miles), then at junction of the Tanana, it flows through Rampart Rapids (100 miles), then 800 miles of meandering river through a channel about 2 miles wide. Forty Mile River drainage basin -- fan-shaped area 100 miles in largest dimension, rugged mountains; prominent feature is the terrace arrangements in valleys. Mission Creek -- asymmetrical basin containing high gradients. Seventy Mile River -- high gradient, benches are prevalent. Birch Creek -- for 60 miles it is confined, maintains a fairly rapid flow, then for 100 miles it meanders in Yukon Flats about 10-20 miles from Yukon River. Beaver Creek -- good gradient in foothills, then it meanders in Yukon Flats. Tanana River -- an asymmetrical valley cut by glacier-fed streams from Alaska Range, fairly broad valley. Tolovana River -- is in a narrow valley (30 miles) at head, then it opens abruptly into a wide valley (40 miles) at confluence of forks, then on leaving foothills it enters deep channel on alluvium, very low gradient,

tortuous stream. Extensive tables of data taken, stream flow, etc. Streams taken up individually, some details included within reports on individual streams. Several maps included within report. Topographic maps showing gaging stations, also some sketch maps, i.e., distribution of vegetation in region covered. Also bibliography of Government papers on area covered. About 50 papers listed.

EMREY, D.J., "Subgrade Soils, Their Analysis and Drainage", *The Canadian Engineer*, Vol. 72, No. 12, pp. 5-9, 23 March 1937 (also Nos. 13 and 15, 30 March and 13 April 1937).

A review of published material (largely from Public Roads Administration, New Hampshire and Michigan sources) on subgrade soils, classification, frost heaving and drainage. Included is a good popularly written review of the theory of frost heaving and a number of figures illustrating installation of underdrains to intercept seepage.

ENO, F. H. "Field Experiments in Subgrade Drainage and Treatment", *Proceedings of the 11th Annual Meeting, Highway Research Board*, Vol. 11, Part I, 1932, pages 178-197

Presents results of 4 experimental projects beneath concrete pavements and 6 projects with traffic bound roads. Comparisons are on basis of crack ratios.

MERTIE, J. B., JR., "A Geologic Reconnaissance of the Dennison Fork District, Alaska", *U. S. Geological Survey Bulletin* 827

Location of area, previous investigations, limitations of this report, geography, drainage, relief, climate, vegetation, animal life, settlements, all covered in introduction. Geology-- sedimentary and igneous rock outcrops -- greenstone, granite, volcanic rocks (early, Recent), limestone, schist (Birch Creek), conglomerates described. Alluvial deposits -- silt bluffs, possibly some glacial deposits, mentioned. Many benches occur, rejuvenation of Forty Mile River erosion to lower base level. Benches exist at various levels. Alluvial deposits are gravel, sand, silts, some to considerable thicknesses. Mineral resources discussed and classified. Coal-lignite is primary mineral of importance.

MERTIE, J. B., JR., "The Yukon-Tanana Region, Alaska", *U. S. Geological Survey Bulletin* 872

Initial surveys, extent of present survey (scale, details, etc) contained. Geography (details on drainage of area, pp. 11-32) covered. Settlements, population, transportation, climate, general information discussed. Geology outcrops of schist (fairly extensive), limestone, sandstones, shales, fossil studies are correlated in description. Unconsolidated deposits exist, not glacial, but much glacial outwash material reworked, smoothed, water-worn. No direct glaciation exists but much material washed into valley -- boulder pavements, soil slumping, alluvial terraces, and deposits. Many

deeply buried channels, cutting into older terraces and deposits. Streams seem to be in cycle of rejuvenation, i.e., islands in Yukon Flats are not growing but are being weathered and dissipated. Other material on igneous rocks, intrusives, geologic history and economic geology, placer deposits, hillside, valley, older alluvium, placers covered in remainder of report. References scattered through report. Geologic map included.

MOFFIT, F. H., "Geology of the Slana-Tok District, Alaska", U. S. Geological Survey Bulletin 904, pp. 54

Discussion of area is covered (geographic) by previous work. Contains information on relief, drainage, transportation, vegetation. Geology of consolidated (schists, igneous rocks, sedimentary) and unconsolidated deposits (glacial, alluvial, colluvial) is given. Extensive glacial deposits are in area. No preglacial deposits in evidence. Slana River shifts its channel over wide flood plain -- moraine still occupying most of valley to about 400-500 ft above river, kettle kame topography, ponds, lakes numerous; some kames relatively dry but moist soil in base gives luxuriant growth of grass. Morainal deposits occur elsewhere but not as conspicuously as in this valley. They occur especially where they are covered with trees. High gravels found at various levels to 2,000 ft above stream. Low benches occur on almost all streams. Description of placer and lake deposits follows geologic data and history. Geologic map of area included as well as some sketch maps and photographs of area.

MOTL, C. L., "Curing Minnesota Frost Boils by Drains", Engineering News-Record, Vol. 106, No. 7, pp. 270-2, 12 February 1931

Discussed are definition and description of frost boils; primary and secondary conditions contributing to frost boil occurrence; depth of frost penetration; and remedial excavation, backfill and/or drainage measures and results in practice.

PARVIS, MERLE, "Regional Drainage Patterns", Thesis, June 1947, Purdue University

This is a very complete paper on the various sections of Indiana covered and also contains much important material on general air-photo interpretation. General survey of previous history of aerial photography, including material on color, importance of drainage patterns, and the classification and significance, is discussed. Then general air-photo interpretation is discussed with particular attention to land form, drainage pattern, erosion features, soil color, and vegetative cover and land use. Origin of stream systems in various types of material is discussed. Important material on drainage pattern types is included. Description of the various types (18 in all) are given together with a sketch of each type. Dendritic patterns, being the most widely spread, are discussed further in another chapter and additional sketches are included to demonstrate them.

Remainder of report is concerned with the physiographic units, drainage characteristics, and drainage maps of Indiana. Numerous photographs included as well as an extensive bibliography (100 titles).

SEELEY, W. L., "How Rains, Cold Weather, Poor Soil Conditions were Licked at Gustavus", Pacific Builder and Engineer, Vol. 51, No. 4, April 1945, pp. 48-54

An article on grading, drainage and paving methods which successfully solved unusually tough problems encountered in building an isolated airport in Alaska's rain belt.

SPENCER, W. T., "Subsurface Drainage in Highway Engineering", Proceedings, Purdue Conference on Soil Mechanics and Its Applications, July 1940, pp. 402-410

Discusses problems in general, including factors which affect flow of drainage of ground water, design of subsurface drains, etc. Discusses additional studies on drainage, properties of soils -- mentions studies being made at Purdue on permeability of soil.

THE ENGINEER SCHOOL, "Airfield Construction -- Airfield Drainage", Instructor's Manuscript, July 1943, p. 12, Fort Belvoir, Va.

Discusses drainage problems, including subsurface, frost action and drainage structure.

THE ENGINEER SCHOOL, "Military Roads -- Drainage Structures and Subgrade Preparations", Instructor's Manuscript, p. 11, May 1944, Fort Belvoir, Va.

Describes basic principles of drainage work for military road construction.

WAR DEPARTMENT, "Subsurface Drainage Investigation 1945-1946, Comprehensive Report", September 1946, Corps of Engineers, Boston District

The purpose of this report is to summarize and correlate the theoretical studies, laboratory model tests, test results from four full scale field test sections and the data obtained from existing airfield drainage installations during the fiscal year 1945-46 and to present design criteria determined therefrom.

#### g. DRILLING AND TEST PITS

GOODELL, B. C., "Soil Boring Tool for Frost Depth Determination", Journal of Forestry, Vol. 37, No. 6, June 1939, pp. 457-459

An illustrated description of a small diameter boring tool (soil tube) for determining depth of frost penetration.

HVORSLEV, DR. M. JUUL, "The Present Status of the Art of Obtaining Undisturbed Samples of Soils", March 1940, Harvard University, Cambridge, Mass.

This report is divided into two main parts. In the first part is given an analytical review of the character and influence of

the various types of disturbance to the soil sample and of the problems encountered in securing such samples with a minimum of disturbance. The second part contains a comprehensive review of the methods and equipment currently used to obtain undisturbed samples of soils in this country and abroad. Bibliography.

MONTGOMERY, R. H., "Precise Levelling on Alaska Highway", Transactions, American Geophysical Union, Vol. 29, No. 1, February 1948

This paper presents the history of precise vertical control in Alaska and the Yukon; discusses particular problems encountered in bench mark construction and description when working in the northern latitudes; and comments on the evidence indicating regional earth movement.

THE ENGINEER BOARD, "Memorandum Report on Methods of Making Borings and Taking Samples in Permafrost", Memo Report, Fort Belvoir, Virginia

WAR DEPARTMENT, "Well Drilling Machine, Rotary-Type, Skid-Mounted, Gasoline Engine-Driven, Failing, Model 314 -- Preparation for Export", Technical Bulletin TB 5-2024-1, 4 December 1943

This bulletin covers general information on the preparation of the machine for overseas shipment. Contains photographs of the machine.

WAR DEPARTMENT, "Well Drilling", Technical Manual TM 5-297, 29 November 1943

This manual covers the development of groundwater sources for military use. It includes detailed construction methods for the important types of wells and gives advantages and limitations of each type. Wells are classified into types according to method of construction as dug, bored, jetted, driven and drilled. Drilled wells, the most important, are covered in greater detail in this manual than the other types.

#### h. EQUIPMENT AND METHODS, LUBRICATION

GOODELL, B. C., "Soil Boring Tool for Frost Depth Determination", Journal of Forestry, Vol. 37, No. 6, pp. 457-459, June 1939

An illustrated description of a small diameter boring tool (soil tube) for determining depth of frost penetration.

THE ENGINEER BOARD, "Report 868 -- Demolition and Exploratory Drilling Tests with Model 43-S Airborne Rotary Well-Drilling Machine", 18 September 1944, Fort Belvoir, Va.

U. S. WEATHER BUREAU, "Circular Q, Pyrheliometers and Pyrhelometric Practice"

WAR DEPARTMENT, "Preventive Maintenance Services -- Well Drilling Machine", Technical Bulletin TB 5-2002-1, 10 January 1945

Discusses before-operation services, during-operation services and after-operation services.

WAR DEPARTMENT, "Snow Tractor, Snow, M7: and 1-Ton Snow Trailer M19", Technical Manual TM 9-1774, 17 April 1944

This manual contains a description of, and procedure for disassembly, cleaning, repair and assembly of the auxiliary transmission, tracks, steering gear, etc.

WAR DEPARTMENT, "Wheeled and Half-track Vehicles: Engine Sludge Formation in Low Temperature Operation", Technical Bulletin TB ORD 28, 3 February 1944

Experience has shown that cold weather or intermittent vehicle operation are particularly conducive to sludge formation and excessive wear. In order to reduce cold weather sludge and engine wear, it is absolutely essential that the cooling system temperature be raised to a minimum of 140° F as soon as possible after starting.

WAR DEPARTMENT, "Cold Weather Lubrication and Service of Combat and Transport Material", Technical Bulletin TB ORD 126, 19 July 1944

The purpose of this bulletin is to augment Lubrication Orders and Technical Manuals. The instructions given herein apply only at temperatures ranging between 0°F and -65°F.

WAR DEPARTMENT, "Questions and Answers Pertaining to Cold Weather Clothing", Technical Bulletin TB QM 3, 28 January 1944

A bulletin of questions and answers concerning clothing and equipage necessary for cold climates.

WAR DEPARTMENT, "Use of Road and Airdrome Construction Equipment", Technical Manual TM 5-252, January 1945

WAR DEPARTMENT, "Principles of Cold Weather Clothing and Equipment", Technical Manual TM 10-275, 26 October 1944

This manual deals with all important items of clothing and equipment used in cold climates and in the mountains. Not everything in the manual is issued to each man or to each unit but all specialized items which are issued to an individual or to a unit should be checked against the appropriate section in this manual.

WAR DEPARTMENT, "Laboratory Soil Testing Set No. 1 and Expedient Tests", Technical Bulletin TB 5-253-1, June 1945, Restricted

This bulletin describes the laboratory soil testing set No. 1 and its use for exploring and testing soils for airfields, roads, and shallow building foundations in theaters of operations.

#### i. FORESTRY, AGRICULTURE, AND VEGETATION

ARCTIC, DESERT AND TROPIC BRANCH, "Handbook of Alaska, Informational

Bulletin No. 18", April 1945, AAF Tactical Center, Office of Assistant Chief of Air Staff, Training Aids Division

General description of Alaska including topography, drainage, inhabitants, travel, climate, vegetation, animals, birds and fish. To be used in conjunction with the Pocket Guide to Alaska, prepared by the Special Service Division, ASF, the Arctic Manual (TM 1-240).

BELOTELKIN, K. T., "Soil-Freezing and Forest-Cover", Transactions, American Geophysical Union, 1941, pp. 173-5, Pt. 1

Depth of and time of soil freezing and rapidity of thawing as related to type of forest cover; effect of snow cover, forest litter, natural internal soil drainage and soil texture on frost penetration.

DAUBENMIRE, R. F., "Plants and Environment, A Textbook of Plant Autecology", John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, NY, 1947

Autecology is a study of the interrelations between the individual and its environment. The environment is essentially those phases of climatology, botany, geology, soils, zoology, chemistry and physics which are more or less concerned with the development and growth of the species. Thus, environment is a composite of many factors which influence plant growth. The author groups these factors into 7 major categories: (1) soil; (2) water; (3) temperature; (4) light; (5) atmosphere; (6) fire; and (7) the biotic factor. In boreal America, which abuts the Polar Region, temperature is often the controlling factor determining whether or not a particular species is established on a given site. Throughout the forested interior of Alaska, the minimum moisture requirement of certain species is generally a contributing factor delimiting distribution. The sections of this text pertaining to soil, water, temperature and the environmental complex are most important.

GRIGGS, R. F., "The Forest Limit in Alaska", Geographical Review, Vol. 24, 1934, pp. 652-3

This is a review of Mr. Griggs' articles: "The Problem of Arctic Vegetation" published in G. Washington Academy of Science, Vol. 24, pages 153-175, 1934, and "The Edge of the Forest in Alaska and the Reason for its Position", published in Ecology, Vol. 15, pages 88-96, 1944. The reviewer says the arctic timber line (coniferous forest), one of the chief vegetational boundaries of the earth, is of "fundamental importance from every point of view". On the Alaska Peninsula, the forest which ends at Kodiak is 250 miles south of the isotherm; east of the McKenzie it is nearly 150 miles in advance of the isotherm of 10°C (50°F).

GRIGGS, R. F., "Timber Lines as Indicators of Climatic Trends", The G. Washington University, Science, Vol. 85, No. 2202, May, 1937, pp. 251-255. (Note: Science is published by the Science Press, Grand Central Terminal, New York, and is the official organ of the American Assoc. for the Advancement of Science, membership in which is attained through

the Secretary of Smithsonian Institution Bldg., Washington DC.)

The important points contained in this article are as follows:

"The forest is advancing in Alaska. Petrof in 1884 and various U.S.G.S. explorers have noted the advances in western and northern Alaska. The most easterly point at which an advancing timber line has been definitely reported is at Wiseman, latitude  $67^{\circ}30'$ , longitude  $150^{\circ}$ , by Robert Marshall..... No fossil pollens except an occasional grain were found in bogs at Kodiak by Dr. Paul W. Bowman (Ecology, 15:97:100, 1934). The general belief among botanists is that tree growth is limited by the isotherm of  $10^{\circ}\text{C}$  ( $50^{\circ}\text{F}$ ). In southwest Alaska the isotherm stands 250 miles beyond the edge of the forest. Now there is a plant migration; apparently the climate of Alaska has become mild so recently that the trees haven't been able to keep up with the change and occupy the terrain suitable for them. The advance is slow, at Kodiak one mile per century, on account of the fact that the ground is thickly covered with vegetation which chokes intruders. The advance in northwest Alaska is probably 1-10 mile per century." It was noted that Canadian white spruce is on the mainland of Alaska and that Sitka spruce is the conifer which has advanced as far as Kodiak.

HALLIDAY, W. E. D. and BROWN, A. W. A., "The Distribution of Some Important Forest Trees in Canada", Ecology, Vol. 24, No. 3, 1943, pp. 353-373, published by Dominion Forest Service, Dept. of Mines and Resources, Ottawa, O., Canada

This paper presents maps showing the distribution of 20 forest trees in Canada, not only the boundaries of their range but also by contours showing population intensity (of the particular species) within this range. Methods and techniques employed in this survey are discussed in detail. Canadian forests are divided into four major biotas: (1) mixed eastern; (2) western mountainous; (3) boreal or northern; and (4) coastal. Of special interest is the boreal forest which is centered in the Yukon Valley. Individual species discussed include white spruce, black spruce, tamarack, aspen, balsam poplar, paper birch, lodgepole pine, and alpine fir. (With the exception of the last two species, all of these trees are common in the permafrost zone of Alaska.) Some plant geographers say that both lodgepole pine and alpine fir occur near the Alaska-Canada boundary line and possibly extend into Alaska proper in the vicinity of the Alaska Range. Special emphasis is placed on the effect on plant distribution produced by the major glaciations. The northern limits of various tree species correspond strikingly with the July isotherm. Other factors contributing to tree distribution include occasional references to soil and moisture conditions, seeding habits of the particular species, and the effect of forest fires and logging operations. Bibliography of 25 papers is included.

HALLIDAY, W. E. D., "A Forest Classification for Canada", Forest Service Bulletin 89, 50 pp., 1937, Dominion Forest Service, Lands, Parks and

Forest Branch, Dept. of Mines and Resources, Ottawa, Canada (price 35¢.)

Canada is divided into 3 broad Climax Formations, the ultimate vegetative cover for a given region. The general divisions are (1) Arctic Alpine Tundra Formations, (2) the Forest Formation, and (3) the Grassland Formation. The widespread nature of the Forest Formation and the varying characteristics and responses to climate of the dominant species in a particular area render it necessary to acknowledge major cover types within the general Forest Formation. The author recognizes 8 Forest Regions in Canada. A brief description of each of the regions is presented. Of special interest is the Boreal Forest Region as all of the Permafrost Zone in Canada falls in this region. A complete check list of tree species occurring in Canada and a bibliography of 39 references is included.

MERRITT, M. L., "Notes on the Western and Northern Distribution of Tree Growth in Alaska", Forest Service Paper, 1931, from "Forests of Alaska", U. S. Dept. of Agriculture Pamphlet.

Discusses the effect of climate on tree growth quoting various authorities, making references to notes on trees planted by the Russians in 1805 at Dutch Harbor. Table I gives temperature and forest cover data regarding various Alaska localities as prepared from data obtained by the U. S. Weather Bureau.

NIKIFOROFF, CONSTANTIN, "Perpetually Frozen Subsoil of Siberia", Soil Science, Vol. XXVI, No. 1, July 1928, pp. 61-79

This article discusses the location, thickness, and temperature of permafrost, particularly in the vicinity of Yakutsk, Russia. The well of Shergren at Yakutsk is stated to be 382 feet deep and the temperature at the bottom to be  $-3^{\circ}\text{C}$ . A hypothesis as to the origin of permafrost is discussed. It is pointed out that the climatic conditions resulting in excess of cold may cause the permafrost. The other theory points out that permafrost may have been caused by glacial action. It is pointed out that agriculture by the Yakuts has been successful in spite of the fact that the growing season is only one hundred days long. Of course, during the growing season, the sun shines from 21 to 22 hours per day. Dairying is the principal agricultural pursuit. A series of maps and graphs illustrating the author's dissertation are included.

PALMER, LAWRENCE J. and ROUSE, CHARLES H., "Study of the Alaska Tundra with Reference to its Reaction to Reindeer and Other Grazing", Research Report 10, Fish and Wildlife Service, U. S. Dept. of Interior, Washington, DC, 1945, 48 pp. (price 45 cents)

The tundra region of Alaska varies in width from a few miles to 200 miles along the Bering Sea and from 100 to 150 miles along the Arctic Coast. Vegetation cover types are largely sedges, grasses, lichens, heaths, and procumbent woody plants. The authors list 16 distinct vegetative types in the report. A map showing the approximate distribution of tundra is included. A detailed list of plants occurring in the tundra regions includes

20 grasses, 25 sedges and reeds, 200 herbaceous plants, 25 woody plants, 40 mosses, and 40 lichens. Throughout the paper, emphasis is placed on forage value, although occasional references are made to soil, moisture and frost conditions, land forms and climatic influences which are of special interest.

**RAUF, HUGH M.**, "Botanical Problems in Boreal America I and II", *The Botanical Review*, Vol. 7, No. 3, pp. 148 to 208, March 1941; Vol. 7, No. 4, pp. 209 to 248, April 1941

The author emphasizes the difficulties encountered in attempting to classify forests or to present logical arguments for the existence of a particular plant association in a given location. This paper is principally a review of literature of approximately 250 papers and a statement of the author's opinions of the other investigators' concepts and methods. The general theme of agreement throughout the paper is that much of the arctic and subarctic vegetation is in a state of flux and still far from a state of equilibrium. A short section of the paper is devoted to a discussion of stone polygons. Briefly, in order to have stone polygons, no vegetation can be present during their development. Thus, if both stone polygons and vegetation are present, the vegetative cover is comparatively recent. Mapping of vegetation by air photos and the construction of cover type maps from air photos is discussed. A complete list of references for detailed climatic conditions in various parts of Canada is given.

**ROTHROCK, J. T.**, "Sketch of the Flora of Alaska", *U. S. Smithsonian Museum Report*, 1867-8, pp. 433-463

This article apparently is based on early explorations immediately subsequent to the acquisition of Alaska by the United States. Although there are some interesting references, undoubtedly more recent publications give greater detail as to the flora of Alaska.

**SHARP, R. P.**, "Ground-Ice Mounds in Tundra", *Geographical Review*, Vol. 32, No. 3, 1942

Description of ground-ice mounds in Wolf Creek region, photographs and cross-sectional sketches included. Mode of origin discussed may be due to hydraulic pressure or of Porstid's "upheaval" type, definitely not entombed ice because of surface indications of upheaval. Discussion of cycles observed in the development of ice mounds and their relation to the tundra topography produced, knobs and depressions more or less mantled by vegetation contained in report. Ground-ice mounds should be considered along with solifluction, frost-heaving and "Palsen" formation in the development of tundra topography.

**SPURR, STEPHEN H.**, "Aerial Photographs in Forestry", *The Ronald Press Co.*, New York, 1948

Although the basic theory of the application of photographic techniques to forest inventory was first worked out by European investigators in 1925, Canadian foresters have employed air photos for timber cruising on a large scale since 1929. It

was not until World War II that the use of aerial photographs in forestry was seriously undertaken in the United States. This book, written by a forestry professor at Harvard, is intended essentially as a text for advanced forestry students having a knowledge of the fundamentals of silviculture and mensuration. A considerable portion of the publication is devoted to technique and methods of photo-interpretation applicable to forest management which is of interest only to a trained forester. However, chapters on the elements of photogrammetry, techniques and principles of photo-interpretation, and especially a detailed discussion of photographic specifications are of definite value to air-photo interpreters in any field.

**TAYLOR, RAYMOND F., "Pocket Guide to Alaska Trees", Miscellaneous Publication No. 55, U. S. Dept. of Agriculture**

Three general types of vegetation occur -- spruce, birch forest of interior; nonforested tundra of Arctic and Bering Sea slopes; dense hemlock, spruce forests of coast. Coastal forests -- existing on Pacific side of Alaska Range from southeastern tip to Kodiak, contains 70 percent hemlock, 25 percent spruce, 5 percent cedar, and others. Interior forests -- existing in rivers and flats, contain spruce-birch, bounded on south by Alaska Range, north and west by tundra, and grasslands. Nonforested areas -- grasslands occur on Alaskan Peninsula, Aleutian Islands, south slopes of Alaska Range. Tundra over vast section bordering Bering Sea and Arctic Ocean north of Brooks Range. Two pages used in brief identification of leaves followed by 27 pages of description of trees -- bark, wood, leaves, etc. and location. Pictures of leaves and cones included. Map accompanying report shows general location of trees -- scale: 1:5,000,000.

**TAYLOR, R. F., "Yield of Second-Growth Western Hemlock-Sitka Spruce Stands in Southeastern Alaska", Technical Bulletin No. 412, March 1934, U. S. Dept. of Agriculture**

A bulletin on the forest crops of southeastern Alaska. Gives the results of a study of growth and yield of even-aged, normally stocked, second-growth stands. The data for the study were obtained on 288 sample plots, varying in size from one-tenth to one acre, laid out in representative young forests. Each plot contained from 150 to 300 trees.

**TOUMEY, J. W. and KORSTIAN, C. F., "Foundations of Silviculture upon an Ecological Basis", 2nd Edition Revised, 1947, John Wiley and Sons, New York**

This volume is divided into three parts. Part I -- Environment of Forests; Part II -- Influence of Forests on their Environment; Part III -- Forests, which includes the basic concepts of plant growth, form and life of forest trees. The following chapters are of special interest with regard to permafrost studies: II -- Solar Radiation; III -- Air Temperature; V -- Climate; VI -- Soil Conditions; VII -- Soil Moisture and Its Influence on Forest

Vegetation; VII -- Physiographic Conditions; IX -- Biotic Factors; XVIII -- Forest Vegetational Units and Their Classification; XIX -- Origin and Development of Forest Communities. A bibliography of over 600 references is included.

U. S. DEPARTMENT OF AGRICULTURE, "The Forests of Alaska", 1 July 1944, Forest Service, Alaska Region

This pamphlet describes the national forests of Alaska, including water power and agriculture, and home sites. A map showing the forest zones of Alaska is included.

U. S. GEOLOGICAL SURVEY, "Photo Interpretation of Vegetation in the Tropical Pacific Area and its Use as an Indicator of Kind of Ground", Engineering Notes No. 20, August 1944, prepared under direction of Office, Chief of Engineers, Military Intelligence Division, Restricted.

This paper is a compilation of such information on tropical Pacific forests and cultivated crops as may be of military value, particularly to engineers. The illustrations include aerial photographs of most of the described vegetation types; these are mounted by pairs so that they can be studied under the stereoscope.

#### **J. GEOLOGY, GLACIATION, GEOMORPHOLOGY, PETROGRAPHY, OIL RESERVES**

BLACK, ROBERT F. and BARKSDALE, WILLIAM L., "Permafrost Program Progress Report No. 5, Terrain and Permafrost, Umiat Area, Alaska", September 1948, Military Geology Section, U. S. Geological Survey in cooperation with Research and Analysis Branch, Engineer Intelligence Division, Office, Chief of Engineers.

This report describes briefly the topography, drainage, climate-vegetation, geology, permafrost and hydrology in the Umiat area of northern Alaska. Two terrain units, the flood plain of the Colville River and the bedrock hills of the Arctic plateaus, are discussed in relation to material, vegetation, permafrost, and construction considerations. Flood-plain deposits of the Colville River in the Umiat area consist of lenticular bars of silt, sand, and gravel formed along active channels, and muck and silt deposits in abandoned drainage channels. Areas of coarse-grained material, favorable for airfield construction, are scattered widely and their extent is limited. Damage to the old camp was caused by the thawing of ice and frozen muck in an old lake basin. Part of the airstrip is slumping because of the thawing of underlying ice wedges and frozen silt. The new camp is on a gravel bar and is relatively free from effects of frost action. The permafrost conditions as described in the report are probably similar to those of other areas in the Arctic plateaus of northern Alaska. Report includes maps of the Umiat area, aerial photograph of Umiat area, mean monthly maximum and minimum temperatures at Umiat, Umiat No. 1, test hole temperature log, and photographs of the area.

**BLACK, ROBERT F., "Permafrost Program, Progress Report No. 2, Permafrost Investigation at Point Spencer, Alaska", U. S. Geological Survey 1946**

Report on an investigation of the regional geologic aspects of permafrost as related to military engineering problems, particularly in regard to selection of airfield sites, so that ultimately, criteria can be established for the accurate forecast of the problems and conditions which will be encountered in permafrost areas of possible military interest that are inaccessible to ground reconnaissance. The immediate aim of the investigation at Point Spencer was to determine the geologic and permafrost conditions with special emphasis on groundwater.

**BROOKS, A. H., "The Geography and Geology of Alaska", U. S. Geological Survey Professional Paper 45, 1906**

A general reconnaissance of the geography and geology of Alaska summarizing all information to 1906. An excellent report of 300 pages, including many photographs, maps, sketch maps (geographic and geologic), and an extensive bibliography on Alaskan literature to 1906. Drainage of all regions is briefly discussed -- each small area taken individually. Climatic investigations are presented in a special section (55 pages). Geology of all Alaska taken up by geologic periods with details on the Quaternary deposition and glacial erosion. Geologic history and study of geomorphology are presented in some detail. Excellent photographs and many helpful sketch and reconnaissance maps are included.

**BROOKS, A. H., "The Kougarok Region", U. S. Geological Survey Bulletin 328, 1908, pages 294-328**

Area includes Bendeleben Mountains on southeast, a low basin to the northwest of the mountains, and to the north the dissected upland. Bedrock is primarily schist and a crystalline limestone. Alluvium, widely scattered, consists of (1) gravels, sands, and clay, underlying modern deposits in valleys; (2) the bench gravels; and (3) the present stream gravels. Brief discussion of geologic history including a sequence of geologic events that lead to present erosional features is set forth. Author then discusses in some detail the various gold placers, including description of deposits; i.e., benches and valley fillings.

**CAPPS, STEPHEN R., "Geology of the Alaska Railroad Region", U. S. Geological Survey Bulletin 907, 1940**

Describes geology and geography of an area 140 miles wide and 450 miles long from north to south reaching from Gulf of Alaska northward into Yukon Basin. Includes illustrations and maps.

**CAPPS, STEPHEN R., "Glaciation in Alaska", U. S. Geological Survey Professional Paper 170-A, 1931**

A discussion mainly of Pleistocene glaciation in Alaska.

CAPPS, STEPHEN R., "The Chisana-White River District, Alaska", U. S. Geological Survey Bulletin 630, 1916

Described general geology and geography of this region with several illustrations and maps.

CAPPS, STEPHEN R., "The Kantishna Region, Alaska", U. S. Geological Survey Bulletin 637, 1919

This bulletin covers an area bounded by the Alaska Range on the south, the Tanana River on the north, the Nenana River on the east, and the lower Kantishna River on the west; the area lies between the village of Nenana and Mt. McKinley. Field work was done in 1916. The geography and geology of this area were undertaken in 1916 because the Alaska Railroad was being built adjacent to this area, and it was anticipated that mining activity would be greatly increased. Coal as well as gold, silver and antimony was found.

CONRAD, V., "Polygon Nets and Their Physical Development", American Journal of Science, Vol. 244, No. 4, pp. 277-296, April 1946

This paper is a summary of studies made by the author in 1933 of a well-developed stone polygon net located in the Hochschwab Mountain group of the East Alps. The small stone polygons, less than 2 meters in diameter, described in this paper, are not related to "soil polygons" in appearance or physical development. There are 3 different hypotheses explaining rock polygons. The theory forwarded by B. Hogborn emphasizes the pushing force of water. In the initial stage of development, the nucleus of an individual stone polygon is a bare spot in a generally rock fragment-littered surface. The fine-grained soil (clay) in the bare spot expands on freezing, resulting in differential sorting of materials according to size, the larger particles being forced towards the perimeter of the bare spot. With recurrent freezings, the size of the bare spot increases. The 2nd hypothesis by Nordenskjöld, Low and Gripp considers convectional currents in an unstable soil caused by temperature differences. The author believes this hypothesis is not applicable to the development of the polygon net he examined, since the formula implies that the basic condition for instability requires a mixing ratio of 60 percent water and 40 percent fine mold. The clayey soils at the location of the polygon net described by the author contained an average moisture content of 35 percent by weight. The last hypothesis by Steche stresses the fact that those soils likely to develop structures have colloid properties. Colloidal substances (between 100 and 1 millimicrons in diameter) swell when mixed with water. The author considers colloidal swelling forces strictly a secondary factor. He is of the opinion that freezing forces are much more important. A detailed statistical analysis of field measurements of 37 polygons is given. An accentuated frequency maximum for polygon interior angles occurs at 120 degrees. This indicates a distinct tendency towards the formation of equilateral hexagons exists. Of the 37 polygons measured, 86 percent of the legs were between 31 to 110 cm long. A bibliography of 28 references

is listed.

EAKIN, H. M., "The Yukon-Koyukuk Region, Alaska", U. S. Geological Survey Bulletin 631, 1916

It is stated in this bulletin that "during the maximum glaciation, the entire lower McKenzie Valley was probably ice filled and that the mountains along the Peel River portage show some evidence of glaciation up to 500 feet and possibly 1500 feet above the sea" -- Eakin quoting R. G. McConnel's "An Exploration in the Yukon and McKenzie Basin" report. A. H. Brooks is quoted as saying in "The Geography and Geology of Alaska", U.S.G.S. Professional Paper 45, page 284, 1906, that "in regard to the character of the Yukon Valley between the mouth of the Tanana and the Yukon Flats that this part of the Yukon Valley represents incised meandering.....". The Yukon-Koyukuk region is about 12,000 square miles in area and lies between the Yukon and Koyukuk Rivers west of the Yukon Flats or approximately from longitude 150° to 157° west and from latitude 65° north to the Arctic Circle. Mountainous areas are a small part of the total area. The largest mountainous area is about 2,000 square miles. There is an unusually striking development of high-level terraces and flat summits and passes in the mountains of the region -- features of a type that is widely distributed in interior Alaska but whose origin has generally been regarded as obscure. "Except on some of the creeks where the gravels are permeated by circulating ground waters and near hot springs, the ground below a slight depth is permanently frozen in place to depths of 130 feet or more. Where snow accumulates in unusual amounts, banks may persist until late in summer or even throughout the season."

EAKIN, HENRY M., "The Iditarod-Ruby Region, Alaska", U. S. Geological Survey Bulletin 578, 1914

This volume is the third report based on work inspired by the discovery of gold in the Innoko district in 1906. In the province extending from Ruby on the Yukon to Iditarod, surveys seem to have established the fact that gold is associated in this district with two distinct series of rocks. The report shows that the bedrock sources of the placer gold of the district include the igneous intrusives and the Cretaceous sediments at or near their contacts with the igneous intrusives. Geologic conditions favorable to the occurrence of auriferous deposits are repeated in many places in this part of Alaska.

EARDLEY, A. J., "Unconsolidated Sediments and Topographic Features of the Lower Yukon Valley", Bulletin of the Geologic Society of America, Vol. 49, pp. 303-342, February 1938

Report contains important material, geologic and topographic, on lower Yukon. Report locates gravel, sand, silts, and muck -- their origin is a problem, but some conclusions are stated. In general, it appears in the most part to be fluvial but the silt a

combination of fluvial and aeolian. Regional topography appears as mature hills rising above lowlands. Much detailed material on local topography presented. Valley shape, stream patterns, stream re-entrants described. Mention of ice lenses, frozen ground. Many good photos to illustrate features discussed and to show general topography of region, many oblique air photographs. Sketches are used to demonstrate text and include valley cross sections, general topography around stream, extent of glaciation in area. Bibliography includes many U.S.G.S. references on Alaska.

ELIAS, M. M. and VOSBURGH, R. M., "Permafrost Program -- Progress Report No. 1, Terrain and Permafrost in Galena Area", 1946, U. S. Geological Survey, Dept. of Interior, Washington, D. C.

This report is a study of terrain and permafrost in a part of one of the large alluvial basins which characterize the topography in central Alaska. The report describes the general terrain of the basin, the relationship of ground and permafrost conditions to topography, suitability of the terrain units for construction, and criteria for interpreting the terrain from aerial photographs. The report presents the results of field investigation of two terraces near the Galena Air Base; the suitability of the two terraces for possible airfield sites is discussed.

FRY, W. H., "Petrographic Methods for Soil Laboratories", Technical Bulletin TB 344, January 1933, U. S. Dept. of Agriculture, p. 95

This bulletin describes in detail the fundamental properties of light, the petrographic microscope, optical methods and the application of methods.

HARRINGTON, G. L. and MERTIE, J. B. JR., "The Ruby-Kuskokwim Region of Alaska", U. S. Geological Survey Bulletin 754, 1924, 136 pages.

Bulletin 754 describes the geography, drainage and geology, and other features of a mining region located south and west of Fairbanks, Alaska extending from Ruby on the Koyukuk River to the Kuskokwim River. The information was gathered from 1896 to 1920 and combines all available information up to the time of preparation of the report. It was prepared principally to assist mining operations in the Ruby-Kuskokwim region.

LEFFINGWELL, E. DeK., "The Canning River Region, Northern Alaska", U. S. Geological Survey, Professional Paper No. 109, pp. 179-243, 1919

An excellent early treatise on ground ice and permanently frozen ground. Included is a discussion of diffusivity of frozen ground.

MENDENHAL, W. C., "Geology of the Central Copper River Region, Alaska", U. S. Geological Survey Professional Paper 41, 1905

Introduction reviews history of area. Geography of Chugach and Wrangell Mountains, Alaskan Range, interior valley and

Copper River areas is given. Geology introduced -- earliest rocks are pre-Silurian with Silurian rocks such as conglomerates, arkoses, shales, and schists. Sediments and volcanics are Carboniferous or Devonian; Carboniferous greenstone and lavas are present. Widespread Permian and Triassic marine influence. Erosion then followed by Eocene sedimentation of fresh water variety. Then post-Eocene uplift, out-pouring of lavas, and Pleistocene silts, sands, and gravels. Description of formations together with some excellent photographs follow.

MERTIE, J. B. JR. and HARRINGTON, G. L., "The Ruby-Kuskokwim Region, Alaska", U. S. Geological Survey Bulletin 754, 1924, p. 136

Describes the general geology and geography of the region. Includes several illustrations and maps.

MERTIE, J. B. JR., "Mineral Deposits of the Ruby-Kuskokwim Region, Alaska", Geological Survey Bulletin 764-C, 1936

This bulletin discusses the geography and geology in connection with the mineral resources of the Ruby-Kuskokwim region in west-central Alaska between the Yukon and Kuskokwim Rivers.

MERTIE, J. B. JR., "Geology of the Eagle-Circle District, Alaska", Geological Survey Bulletin 816, Department of the Interior, 1930

This bulletin covers the area along the Yukon River between Circle and Eagle, from Circle upstream to the United States boundary. This bulletin discusses the geography and geology as well as climate and mining in an area which has been very active as a gold mining region since 1897. The work is based on field work by the writer in 1925 and includes references to statements from all prior geology work in this area. It is illustrated with many photographs and diagrams. A very brief reference to permafrost indicates that it has restricted the circulation of the deeper groundwater.

MERTIE, J. B. JR., "A Geologic Reconnaissance of the Dennison Fork District, Alaska", U. S. G. S. Bulletin 827

Location of area, previous investigations, limitations of this report -- geography drainage, relief, climate, vegetation, animal life, settlements -- all covered in introduction. Geology -- sedimentary and igneous rocks outcrops -- greenstone, granite, volcanic rocks (early, Recent) -- limestone, schist (Birch Creek) conglomerates described. Alluvial deposits -- silt bluffs, possibly some glacial deposits, mentioned. Many benches occur -- rejuvenation of Forty Mile River erosion to lower base level. Benches exist at various levels. Alluvial deposits are gravel, sand, silts -- some to considerable thicknesses. Mineral resources discussed and classified. Coal-lignitic is primary mineral of importance.

MERTIE, J. B. JR., "The Yukon-Tanana Region, Alaska", U.S.G.S. Bulletin 872

Settlements, population, transportation, climate and general information are discussed. Geology outcrops of schist (fairly extensive) limestone, sandstones, shales, fossil studies are correlated in description. Unconsolidated deposits exist -- not glacial, but much glacial outwash material reworked, smooth-bed, water-worn. References are scattered through report. Geologic map is included.

MERTIE, J. B. JR., "The Chandalar-Sheenjek District, Alaska", U. S. Geological Survey Bulletin 310-B, 1929

This bulletin discusses the geography and geology in connection with the mineral resources of the Chandalar-Sheenjek Rivers as well as streams in the vicinity. This area is located directly north of Fort Yukon on the Yukon River and extends up to the Brooks Range. The work was done in 1926 and 1927.

MOFFIT, FRED H., "Geology of the Nutzotin Mountains, Alaska", Geological Survey Bulletin 933-B, 1940, pp. 103-174

This paper deals primarily with the geology of the part of the Nutzotin Mountains extending southeastward from the Nabesna River to Beaver Creek and the boundary between Alaska and the Yukon Territory. This area includes the Nabesna gold mine, on White Mountains, and the Chisana placer-gold district near the head of the Chisana River, both of which have been important producers of gold. The field work represented on the geologic map was partly a revision of work previously done by the writer and others and partly an extension of mapping into areas hitherto unmapped.

MOFFIT, FRED H. and MERTIE, J. B. JR., "The Kotsina-Kuskulana District, Alaska", Geological Survey Bulletin 745, 1923

A geological survey to determine, examine and map in detail copper-bearing areas which give promise of yielding commercial ores. Survey was made in the Kotsina-Kuskulana district in the part of Alaska known as the Copper River region. It lies at the west end of Chitina Valley on the southwest slope of the Wrangell Mountains.

MOFFIT, F. H., "Geology of the Nome and Grand Central Quadrangles-Alaska", U. S. Geological Survey Bulletin No. 553, pp. 53-54, 1913

Restatement of Tyrrell's description of "Crystosphenes or Buried Sheets of Ice in the Tundra of Northern America"

MOFFIT, FRED H., "Geology of the Upper Tetling River District, Alaska", U. S. Dept. of Interior, Geological Survey Bulletin 917-B, 1941

The term "upper Tetling River district" is here applied to a small part of the Alaska Range lying northeast of the Wrangell Mountains and extending from Suslota Pass to the Nabesna River. The rocks of the district are predominantly sedimentary, but include lava flows and tuffs, and areas of granitic intrusives. The district is strongly glaciated, and its unconsolidated deposits therefore include morainal

material as well as the usual sand, silt, and gravel of the streams and lakes. Evidences of gold and molybdenum have been found.

MOFFIT, F. H., "Geology of the Slana-Tok District, Alaska", U. S. Geological Survey Bulletin 904, pp. 54

Discussion of area is covered (geographic) by previous work. Contains information on relief, drainage, transportation, vegetation. Geology of consolidated (schists, igneous rocks, sedimentary) and unconsolidated deposits (glacial, alluvial, colluvial) is given. Extensive glacial deposits are in area. No preglacial deposits in evidence. Slana River shifts its channel over wide flood plain -- moraine still occupying most of valley to about 400-500 ft above river; kettle kame topography; ponds, lakes numerous; some kames relatively dry but moist soil in base gives luxuriant growth of grass. Morainal deposits occur elsewhere but not as conspicuously as in this valley. They occur especially where they are covered with trees. High gravels found at various levels to 2,000 ft above stream. Low benches occur on almost all streams. Description of placer and lake deposits follows geologic data and history. Geologic map of area included as well as some sketch maps and photographs of area.

NORDENSKJOLD, OTTO and MERKING, LUDWIG, "Geography of the Polar Regions, Consisting of a General Characterization of Polar Nature by Otto Nordenskjold, and a Regional Geography of the Arctic and the Antarctic by Ludwig Merking", American Geographical Society, New York, 1928, Special Publication No. 8, pp. 1-90, Translated by Dr. Einst Anteus.

The presence of the polar regions of today enables scientists to visualize more clearly the conditions existing during the ice age. The climate, the ice covering and the sparse vegetation are the 3 main factors which make polar nature what it is. With respect to climate, summer temperatures are far more important than winter temperatures on the characteristics of polar nature. Precipitation and wind velocity are of certain importance. The change of light conditions between summer and winter (daylight and darkness, in effect), the fauna and certain features of land forms are of minor importance. One of the major benefits which can be gained from knowledge obtained from polar research is to obtain a more accurate picture of "what happened" during the Pleistocene. The author, a geography professor at the University of Gothenburg (Sweden) has assembled climatological data and information of the flora and fauna gathered by numerous expeditions to various parts of the Arctic and Antarctic. A brief reference is made to soil forming agencies and soil formations, especially solifluction, polygonal soils, soil stripes and typical land forms occurring in polar regions. The author suggests that permanently frozen ground should be distinguished from layers of pure ground ice occurring directly beneath a thin vegetation mantle, found in Alaska, Siberia, and especially in the New Siberian Islands. A bibliography of 24 references, principally European Polar

Expedition papers, is included.

PEWE', TROY L., "Permafrost Program Preliminary Report, Permafrost Investigations, Fairbanks Area, Alaska," Military Geology Section, U. S. Geological Survey in cooperation with Research and Analysis Branch, Engineer Intelligence Division, Office, Chief of Engineers, September 1948

This report summarizes the progress of terrain and permafrost investigations in 1947 in the Fairbanks area, Alaska. The purpose is to make available preliminary interpretations of permafrost conditions in the Fairbanks area prior to the completion of the project. To supplement the general terrain and permafrost investigations, geophysical investigations of the permafrost will be initiated in the summer of 1948 in the Fairbanks area. In 1947, permafrost information was obtained from foundation excavations, hydraulic mining areas, wells, and drill holes. Depth to permafrost was determined in many places with steel hand augers. D. J. Cederstrom of the Water Resources Branch of the U. S. Geological Survey studied the groundwater conditions of Fairbanks concurrently with the terrain and permafrost investigations of the area and will continue the study of the groundwater resources in 1948. In February and April 1948, data on groundwater in the Fairbanks area were released; tables of data on approximately 500 wells were put on file for public inspection at the Geological Survey in Washington, D. C., and in Fairbanks and Juneau, Alaska, and at the office of the City Engineer in Fairbanks. Report includes preliminary permafrost map of the Fairbanks area and sketches on distribution of permafrost and artesian conditions of water confined by permafrost in the Fairbanks area.

SHARP, R. P., "Ground-Ice Mounds in Tundra", Geographical Review, Vol. 32, No. 3, 1942

Description of ground-ice mounds in Wolf Creek region, photographs and cross-sectional sketches included. Mode of origin discussed may be due to hydraulic pressure or of Porslid's "upheaval" type, definitely not entombed ice because of surface indications of upheaval. Discussion of cycles observed in the development of ice mounds and their relation to the tundra topography produced, knobs and depressions more or less mantled by vegetation contained in report. Ground-ice mounds should be considered along with solifluction, frost heaving and "Palsen" formation in the development of tundra topography.

SMITH, P. S., "The Noatak-Kobuk Region, Alaska", U. S. Geological Survey Bulletin 536, 160 pp., 1913 (out of print).

This bulletin contains reference to "a list of specimens of flora" in W. C. Mendenhall's Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska, U. S. Geological Survey, Professional Paper No. 10, 1902, which is also out of print.

SMITH, P. S. "Areal Geology of Alaska", U. S. Geological Survey, Professional Paper 192, 1939

A description of general kinds and areal distribution of the major subdivisions of the different geologic formations that make up the visible rocky crust of the earth in Alaska.

SMITH, P. S. and MERTIE, J. B. JR., "Geology and Mineral Resources of Northwestern Alaska", U. S. Geological Survey Bulletin 815

Introduction -- past and present reports, including discussion of authors' trips is included. Relief and drainage of (1) general features, (2) Koyukuk plateaus, (3) Brooks Range province, (4) Arctic plateaus, and (5) Arctic coastal plain. Description of climate, vegetation, wild life and population included. Geology broken down into periods for discussion; a very good table showing age and type of rocks in Northwestern Alaska, Chandalar-Koyukuk region, Canning River region, Porcupine Valley region, and Eagle-Circle district contained in report. Good topographic and geologic reconnaissance maps of area. Many photographs that are of value in description of text.

SOLOMONS, T. S., "Surface Features of Northern Alaska", Appalachia, Vol. XII, No. 1, 6 May 1908

Good descriptive article of Alaska. Very little of scientific value.

ST. AMAND, PIERRE, "The Central Alaska Earthquake Swarm of October 1947", Transactions, American Geophysical Union, Vol. 29, No. 5, October 1948

The earthquake swarm of October 1947 is discussed. Investigation of the activity is described. Photographs of earthquake activity are included along with an isoseismal map and a plot of epicenters. The only item of interest insofar as permafrost is concerned is the following statement regarding wells: "Increased turbidity was observed in many wells. The Brazil family, residing between Fairbanks and College, reported an increase in their well water. The well at the Experimental Farm began producing copiously for the first time since it was drilled." It may also be noted that wells that had been pumped before began to discharge water freely at Nenana. Intensities of over 200 tremors are noted; this information may be used for structural design.

TABER, STEPHEN, "Frost Heaving", The Journal of Geology, Vol. XXXVII, No. 5, July-August 1929

This paper describes a laboratory investigation of problems connected with frost heaving. The principles developed have applications in geology, plant physiology, and engineering. Pressure effects accompanying the freezing of soils are due to the growth of ice crystals and not change in volume. Pressure is developed in the direction of crystal growth, which is determined chiefly by the direction of cooling. Heaving is often greater than can be explained by expansion. It is due to the segregation of water as it freezes, more water being drawn up by molecular cohesion. The chief factors

controlling segregation and excessive heaving are: size of soil particle, amount of water available, size and percentage of voids, and rate of cooling. Differential heaving is due chiefly to differences in soil texture and in the amount of available water, but differences in the kind and amount of soil cover are also factors.

TUCK, RALPH, "The Loess of the Matanuska Valley, Alaska", The Journal of Geology, Vol. XLVI, No. 4, May-June 1938, The University of Chicago Press

In 1935, the colonization of a part of the Matanuska Valley in south-central Alaska was undertaken by the Federal Government. Fertile and deep soil for agricultural use is limited in extent. The soil is loess. The part that glaciation may play in the formation of such deposits is clearly demonstrated in present-day glacial action.

UNIVERSITY OF ALASKA, "Earthquake Report for Interior of Alaska", 5 November 1947, College, Alaska, for Commanding Officer, U.S.A.A.B., Ladd Air Force Base, Alaska

A summary of the present knowledge and opinion of members of the University of Alaska in the matter of earthquakes in the interior of Alaska.

U. S. GEOLOGICAL SURVEY, "Alaska Volcano Investigations, Report No. 2: Progress of Investigations in 1946", written for the Corps of Engineers, Department of the Army

In the interests of protecting military installations from destructive volcanism, the War Department, in October 1945, requested the Geological Survey to undertake a program of volcano research in the Aleutian arc. The general objective of the program is the collection and interpretation of geologic information which may be applicable to military operations in this area of active volcanism, with the ultimate aim of developing techniques for predicting the nature, location, and time of volcanic eruptions near military establishments.

U. S. GEOLOGICAL SURVEY, "Terrain Intelligence, Revised Report, Strategic Engineering Study No. 27, Alaska", written for Strategic Studies Unit, Intelligence Branch, Corps of Engineers, April 1943, Confidential.

This report consists of a folio of maps and explanatory tables outlining the principal geographic and related features of Alaska. They cover such subjects as terrain, climate, water supply, construction, transportation, geology and mineral resources.

WALLACE, ROBERT E., "Terrain Analysis in the Vicinity of Northway, Alaska with Special Reference to Permafrost", Permafrost Program Progress Report No. 3, July 1946, U. S. Dept. of Interior, Geological Survey.

This report describes the permafrost conditions, ground types, construction considerations, and methods of identification of five major terrain divisions, their subdivisions, and their

associated lakes in the vicinity of Northway in the Upper Tanana River Basin of eastern Alaska. The five terrain divisions are river flood plains, sand dunes, lake-sediment terraces, alluvial fans, and bedrock areas. A major purpose of the investigation resulting in this report was to determine the relationship of permafrost to terrain types in the Northway area so that ultimately criteria can be established for the prediction of permafrost conditions in areas of possible military importance not accessible for ground investigation. Emphasis was placed on the use of aerial photographs in the analysis of terrain divisions.

WALLACE, ROBERT E., "Cave-In or Thermokarst Lakes in the Nabesna, Chisana, and Tanana River Valleys, Eastern Alaska", Permafrost Program Progress Report No. 4, 1946. U. S. Dept. of the Interior, Geological Survey

Report on a study to develop criteria to be used in determining permafrost conditions by means of aerial reconnaissance. The present study of cave-in lakes in the Nabesna, Chisana and Tanana River valleys of eastern Alaska is part of an investigation of permafrost by the Geological Survey.

#### K. GEOPHYSICAL EXPLORATION

CALLENDAR, H. L. and MCCLEOD, C. H., "Observations of Soil Temperatures with Electrical Resistance Thermometers", Proceedings and Transactions, Royal Society of Canada, Second Ser., Vol. 2, Sec. 3, pp. 109-126, May 1896

A continuation of the May 1895 (1895-1) report by the senior author giving more complete data on soil temperatures. The data are presented in the form of an isothermal diagram, March 1895 to April 1896, and curves showing variation in temperature with depth. A table of thermal diffusivity values are given for various seasons of the year for various depths.

DAY, P. R. and BODMAN, G. B., "Thermoelectric Method of Determining the Freezing Points of Soils", Proceedings, Soil Science Society of America, Vol. 2, pp. 65-71, 1937

The authors state objections to the commonly used method of determining freezing points of soils by means of the Beckman thermometer and describe equipment for thermoelectric measurement of freezing points. Experimental data on the effect of pre-cooling temperatures on the freezing point and data on freezing point depression-moisture content relationships are given.

SHEPARD, E. R., "Subsurface Explorations Made by Resistivity and Seismic Methods", Public Roads, Vol. 16, No. 4, June 1935, p. 57

This article discusses, in detail, with numerous examples, illustrations and photographs, the equipment and technique of subsurface exploration using resistivity and seismic methods. A list of 12 references is given.

U. S. WATERWAYS EXPERIMENT STATION, "Seismic and Resistivity Geophysical Exploration Methods", Technical Memorandum 198-1, 20 January 1943, Vicksburg, Mississippi

This report sets forth the results of an investigation into the practicability of utilizing the seismic refraction and electric resistivity methods of geophysical exploration for the purpose of expediting as well as reducing the cost of the present boring methods of subsurface investigations in the alluvial valley of the Mississippi River.

## 1. HEAT

CARSLAW, H. S., "Introduction to the Mathematical Theory of the Conduction of Heat in Solids", Dover Publications, New York, 1945

Includes a discussion of all the important boundary problems associated with the equation of conduction. In Chapter I, the differential equation of conduction is obtained and some general theorems as to its solution are established. Chapter II deals with Fourier's ring. The next two chapters are devoted to linear flow. Chapters V and VI deal with 2-dimensional problems and flow of heat in a rectangular parallelepiped, Chapter VII deals with the circular cylinder, Chapter VIII with the sphere and cone, Chapter IX with sources and sinks, and Chapter X with Green's functions. Chapter XI deals with the use of contour integrals in the solution of the equation of conduction, and Chapter XII deals with the use of integral equations in the solution of the equation of conduction.

JAKOB, M. and HAWKINS, GEORGE A., "Elements of Heat Transfer and Insulation", John Wiley and Sons, Inc., New York, 1942

This book discusses three kinds of heat transfer, conduction, convection, and radiation, separately and in combinations. A chapter is devoted to the basic property of thermal conductivity with particular attention to practical insulation. Unsteady state equations are made clear to the student by some graphical representations. Dimensional analysis is dealt with in the most elementary manner. Some applications of heat transfer in experimental engineering and the interdependence of heat transfer and surface friction form the subject of the last three chapters.

MERSMAN, W. A., BERGGREN, W. P. and BOELTER, L. M. K., "The Conduction of Heat in Composite Infinite Solids", University of California, Publications in Engineering, Vol. 5, No. 1, 1942, 22 pp.

Analytical and graphical solutions for temperature as a function of position and time in a dissimilar series of semi-infinite solids placed in "imperfect" contact on a plane interface.

NORGAARD, H., "Long-Distance Heating Systems Insulated with Cell Concrete", 25 Years of Civil Engineering, Christiani and Nielsen, 1904-1929, pp. 154-259

Photographs and discussion of various installations using cell concrete insulation produced by using the patent foam compound of Christiani and Nielsen.

PATTEN, HARRISON E., "Heat Transference in Soils", U. S. Dept. of Agriculture, Bureau of Soils, Bulletin No. 59, 1909, 54 pp.

The results of laboratory experimental study and review of literature on the thermal properties of soils. Presented are experimental and derived data on heat of wetting, diffusivity rate, relation between surface area, moisture film, and heat conductivity and diffusivity for seven soils ranging from coarse quartz to clay.

SCHACK, ALFRED, "Industrial Heat Transfer", John Wiley and Sons, Inc., New York, 1933 (Translated from the German by Hans Goldschmidt, Dr.-Ing. and Everett P. Partridge, Ph.D.)

This book discusses (a) The Three Ways in Which Heat is Transferred and the Surface Conductance; (b) Analysis of the Three Mechanisms for Heat Transfer; (c) Calculations for Heat Exchangers; (d) Heat Transfer in Industrial Furnaces; (e) Heat Transmission and Pressure Drop; (f) Numerical Examples in Heat Transfer; (g) Compilation of the Most Important Equations for Heat Transfer; and (h) Important Physical Constants for Heat Transfer.

#### m. ICE AND SNOW

BARNES, H. T., "Ice Formation", 1st Edition, New York: John Wiley and Sons, 1906, 260 pp.

A treatise on the formation of ice. This reference pertains to that part of the text which deals with the theory of the formation of ice in water, and the formation of frazil ice (masses of spicule ice in flowing streams) and anchor ice (ice anchored to the bottoms of streams).

BARNES, H. T., "Ice Engineering", Montreal, Renouf Publishing Co., 1928, 364 pp.

Comprehensive treatise on properties of ice. Specific reference is made to data on latent heat of fusion; latent heat of vaporization; specific heat of ice; thermal conductivity of ice, snow and water; and coefficient of expansion of ice.

COLEMAN, A. P., "Ice Ages Recent and Ancient"

"The largest tree now growing in Spitzbergen is a willow which scarcely rises three inches above the ground. The Arctic regions have enjoyed genial periods and some parts of the tropics have suffered Arctic cold showing that in the past there have been very important variations of climate." "Seams of excellent coal .....and great fossil leaves belonging to trees of a warm climate in beds of Cenozoic age are found in Spitzbergen."

EAGER, WM. L., "Icing Studies, F-2", Public Roads Administration, 1944

This folder consists of a series of letters written to the Public Roads Administration by engineers engaged in the construction and study of icing conditions along the Alaska Highway, principally in Canada. It points out the various serious icing areas

and the corrective measures employed at various points along the road between Whitehorse, Y. T. and Fort St. John, B. C. It is of interest to note that when the snow cover is heavy in the ditches along the highway, the small channels open in the culverts in the road are in general sufficiently protected to function satisfactorily until increasing flows caused by thawing exceed the capacity of the culvert. Often thawing out a frozen culvert with a steam jet provides sufficient waterway capacity to prevent icing by use of the snow and ice cover to protect the stream flow. It is noted that cleaning out culverts thoroughly in anticipation of the spring flow may often be useless if a condition arises causing a slight flow due to thawing through the empty culvert, since the culvert immediately ices up and becomes blocked necessitating retlawing and cleaning out prior to spring flow.

EAGER, WM. L. and PRYOR, W. T., "Ice Formation on the Alaska Highway", Public Roads, Vol. 24, No. 3, pp. 55-74, January-February-March 1945

A treatise on the formation of surface ice. Includes discussion of factors associated with icing and methods to prevent or reduce icing on new construction.

ENGINEERING NEWS-RECORD, "Clearing Snow at a Northern Airbase", Vol. 135, No. 12, 20 September 1945, pp. 107-111

Plenty of snow-handling equipment, operated by regularly assigned enlisted personnel, under direction of the post engineer, has kept the Presque Isle Airfield in northern Maine always ready for traffic. Trucks with one-way plows do most of the work with blowers used to boost the snow over the runway lights where the plows again push it to the edge of the safety strip. A plow with a powered vane in the wing is used to cut down the final bank left by the plows. Notes on snow handling at several other northern fields are appended.

GERDEL, R. W., "The Dynamics of Liquid Water in Deep Snow-Packs", Transactions, American Geophysical Union, Vol. 26, 1945

Good data on thermal and water quantity & snow.

HUNT, HAL W., "Fighting Snow to Keep 'Em Flying", Engineering News-Record, Vol. 129, No. 19, 5 November 1942, pp. 89-100

With regard to the removal of snow from Alaskan airfields, the following is quoted from this article: "Alaskan procedure on preparing and maintaining snow surfaces is substantially different from that described as Canadian practice, perhaps due to the different characteristics of the snow..... Dragging with the proper equipment has proven the most efficient method of field maintenance, with the exception of actual snow removal, according to our Alaskan informant." The remainder of this article describes snow removal from airfields in the States and in Canada. Briefly, the consensus is that the one desirable method of handling snow on airports is to get it off, and keep it off, the runways at all times. The

means of removing snow from runways most favored are machines that pick up the snow and deposit it well away from the used areas. This is usually done by plows, powered by high-tractive-effort trucks, working with rotary blowers or other snow throwing machines.

MULLIS, I. B., "Illustrations of Frost and Ice Phenomena", Public Roads, Vol. 11, No. 4, pp. 61-79, June 1930

The author illustrates various forms of detrimental frost phenomena and discusses and presents data on volume change-temperature change characteristics of water and ice; pressure effects due to frost action; direction of heat radiation; size of soil particle; and the amount of water available.

PAULSON, JOSEPH B. JR., "A Method of Calculating the Effect of Snow on Runoff During Rainstorm", Transactions, American Geophysical Union, 1944, p. 17

Appears to be good method; gives resulting runoff intensity which exceeds sum of rain and snow-melt intensities due to storage of snow-melt in snow cover for first stages of melt.

STEFANSSON, V., "Underground Ice in Northern Alaska", American Geological Society Bulletin, Vol. 42, No. 5, May 1910, pp. 337-345

A description of ground ice in northern Alaska. Four different processes by which the author..... "has seen underground ice formed....." are described.

TABER, S., "Pressure Phenomena Accompanying the Growth of Crystals", Proceedings, National Academy of Sciences, Vol. 3, No. 4, April 1917, pp. 297-302

A historical study of the results of experiments made by various investigators to determine the magnitude of force which accompanies the growth of crystals. The author includes mention of his work and explains the pressure phenomena which accompanies crystal growth.

TABER, S., "The Growth of Crystals Under External Pressure", American Journal of Science, Fourth Ser., Vol. 41, No. 246, June 1916, pp. 532-556

Discusses the phenomena associated with growth of crystals in an alum solution and in a copper sulphate solution and relates such crystal growth to the growth of ice crystals associated with frost heave.

TABER, S., "Surface Heaving Caused by Segregation of Water Forming Ice Crystals", Engineering News-Record, Vol. 81, No. 15, pp. 683-4, 10 October 1918

A discussion of articles by J. L. Harrison, Engineering News-Record, Vol. 80, No. 9, pp. 418-420, 28 Feb. 1918, and C. D. Norton, Engineering News-Record, Vol. 80, No. 22, p. 1058, 30 May 1918, in which Taber disputes their claims and presents his hypothesis on the formation of ice layers and the cause of frost heave.

TYRRELL, J. B., "Crystospheres or Buried Sheets of Ice in the Tundra of Northern America", Journal of Geology, Vol. 12, No. 3, p. 234, April-May 1904

Mr. Tyrrell presents theories which he thinks account for the formation of glaciers, the surface masses of ice formed each winter by the overflow of springs and ground ice. He suggests that the name "crystocene" (derived from the Greek words "ice" and "fountain") replace the name "glacier", and also suggests the name "crystosphere" (derived from the Greek words for "ice" and "wedge") for ground ice or the ice wedges existing below the ground surface. His theory for the formation of underground ice is that underground flows of water have come to the surface in the form of springs, "freeze at the surface and the ice continuing to form downward until, a few feet below the surface, but still within the influence of the external low temperature, a plane of weakness is reached in the stratified frozen vegetation or alluvial deposit, such planes of weakness being generally determined by the presence of thin bands of silt or fine sand.....and there the main body of the ice wedge is formed". Location discussed is the Klondike country.

#### n. INSULATION

CHRISTIANI AND NIELSEN, "Cell Concrete on Floors", Copenhagen, 8 March 1940

This bulletin discusses the construction of cell concrete as insulation material and an underlay for flooring. Construction details are set forth and illustrated with photos and drawings.

CHRISTIANI AND NIELSEN, "District Heating Systems in Denmark with Cell Concrete Insulation"

This bulletin discusses the matter of insulating heat plants using cell concrete as a material for insulation. Most of the plants used as illustrations are located in Denmark.

CHRISTIANI AND NIELSEN, "Circular No. 22, Cell Concrete", 1 December 1926

Part I deals with cell concrete, its properties and application. Part II deals with the normal manufacture of cell concrete and how it is cast and treated. Both Parts I and II are illustrated with drawings and tables which assist greatly in the preparation of cell concrete.

DUFTON, A. F., "Thermal Insulation in Buildings", Royal Institute British Architects Journal, Vol. 52, No. 3, January 1945, pp. 97-99

Use of insulation to obtain better rate of temperature use when building is cold, rather than to help maintain uniform temperature; experiments on effectiveness of various thin insulating layers. Bibliography.

JAILLITE, W. MARKS, "Permafrost Research Area", The Military Engineer, September 1947, Vol. XXXIX, No. 263, pp. 375-379

This article describes construction by the Corps of Engineers, D. A., of a research area near Fairbanks, Alaska for the purpose of studying the effect of permafrost (permanently frozen ground) on various types of foundations, using different kinds of insulation, piling, gravel fills, etc. Some of the difficulties of construction are described, including what happens when flowing artesian well is obtained when drilling for water through the frozen ground.

JAKOB, M. and HAWKINS, GEORGE A., "Elements of Heat Transfer and Insulation", John Wiley and Sons, Inc., New York, 1942

This book discusses three kinds of heat transfer; conduction, convection, and radiation, separately and in combinations. Chapter I is devoted to basic property of thermal conductivity with particular attention to practical insulation.

UNIVERSAL ZONOLITE INSULATION COMPANY, "Zonolite Concrete Manual", Universal Zonolite Insulation Company, Chicago, Illinois, 1945

This manual describes zonolite concrete aggregate and its various densities, compressive strengths and insulating values of various mixes. Specifications for mixing, placing, curing and drying, as well as specifications for use as roof fill and notes on precast zonolite blocks and laboratory test reports are included.

#### o. MAPS, MAPPING, AERIAL RECONNAISSANCE

AMERICAN SOCIETY OF PHOTOGRAMMETRY, "Manual of Photogrammetry", Pitman Publishing Co., New York-Chicago, 1944, 819 pp.

This book discusses the following subjects: Principles of Surveying; Photogrammetric Optics; Cameras; Photographic Mission; Materials and Laboratory Technique; Geometric Characteristics; Stereoscopy; Interpretation; Radial Plotting Methods; Photographic Mosaics; Stereoscopic Mapping Methods; Analytical Computations; Mapping from Oblique Photographs; Field Inspection and Completion; and Training and Application. Includes numerous photographs, maps and drawings.

ASK, REYNOLD E., "Fundamentals of Photogrammetric Engineering", Engineering News-Record, Vol. 133, No. 24, 14 December 1944, pp. 84-89

This article considers topographic mapping including the use of various types of plotting equipment and methods such as the stereocomparagraph, the KEK plotter, the Brock process and the multiplex equipment; and military mapping including the Tri-Metrogon method, the continuous-strip camera, and night photography.

BELCHER, DONALD J., "The Engineering Significance of Soil Patterns", Engineering Experiment Station, Purdue University, Lafayette, Ind., December 1944, Reprint No. 13 from Proceedings, Twenty-third Annual Meeting, Highway Research Board, November 1943

The term soil pattern is used in the comprehensive sense that

includes not only the color pattern of soils but the numerous other factors recorded in an aerial photograph that are influenced by the soil. When properly evaluated, they indicate the engineering properties of the soil. A number of extensive soil areas are described in detail and test data showing their uniformity are presented. Photographs of these areas are included to illustrate their respective patterns.

**BELCHER, DONALD J., "Identifying Landforms and Soils by Aerial Photographs", Proceedings, Thirtieth Annual Road School, Purdue University, 24-26 January 1944, Extension Series No. 56**

Information on the engineering characteristics of soils can be obtained from aerial photographs providing a background of knowledge concerning the area being studied is available. The land form is the key to the type of parent material and the parent is the key to the general physical properties of the soil. Factors observed in analysis of aerial photographs include relief, drainage pattern, erosion, color pattern, vegetative cover, and land use. Bibliography.

**BELCHER, D. J., "The Development of Engineering Soil Maps", Engineering Bulletin, Purdue University, Vol. XXVII, No. 2, March 1943, pp. 86-92**

Engineering soil maps are made to indicate areas in which similar engineering soil problems can be expected. They are a source of information concerning soil types and drainage for planning highways and other construction projects.

**EARDLEY, A. J., "Aerial Photographs and the Distribution of Constructional Materials", Proceedings, 23rd Annual Meeting, Highway Research Board, 1943, pp.557 to 568**

Sources of data on the distribution of constructional materials in an area are contained on soil maps and geologic maps; and aerial photographs should be considered as another form of map for distribution studies. Since detailed soil and geological maps are not available everywhere, aerial photographs may be the only source of information preliminary to field surveys. Aerial photographs may best be interpreted by considering them as soil or geologic maps. Soil and geologic maps are briefly described and their relation to aerial photographs is illustrated. The examples contained in this report demonstrate the great utility of aerial photographs in mapping soil types as well as hard rock formations.

**FROST, ROBERT E., "Identification of Granular Deposits by Aerial Photography", Proceedings, Twenty-fifth Annual Meeting, Highway Research Board, 1945, pp. 116-129**

This paper discusses the techniques used to interpret granular materials from aerial photographs. This method of granular surveying is of great importance to highway and airport engineering because good sand and gravel are always at a premium whether it be as a source of borrow for subgrade improvement, base courses, for concrete aggregate, or for location purposes.

Since the average pattern produced by granular materials is one of the easiest to identify, it is possible to make an air-photo survey of an exceedingly large area in a very short time.

FROST, ROBERT E. and MOLLARD, J. D., "New Glacial Features Identified by Airphotos in Soil Mapping Program", Proceedings, Twenty-sixth Annual Meeting, Highway Research Board, 1946, pp. 562-577

At the outset of the current soil mapping program, from aerial photographs of the State of Indiana, certain glacial air-photo patterns were found to be very complex and, as a result, an endeavor was made to trace the glacial features which have complicated the patterns. The first part of this paper discusses the areal soil mapping program and how it is being done from aerial photographs. The common bedrock and glacial patterns are discussed and illustrated so that the reader may better understand the complex patterns. The remainder of the paper discusses many of the complex patterns and the glacial features which cause them to be developed.

FROST, R. E., "The Use of Aerial Maps in Soil Studies and Location of Borrow Pits", Purdue University, Reprinted from Kansas Engineering Experiment Station Bulletin 51, 1 July 1946

This article deals with the use of aerial maps in soil studies as indicated in the title. It points out that one of the chief advantages of mapping soils from aerial photos lies in the fact that detailed soil maps cannot be made in any other way at a comparable cost, or made as efficiently from the standpoint of time. The basis for this is that soil and rock patterns are repetitive in their natural environment which means that any two materials derived from the same soil or rock pattern material, under the same climate and both occupying the same relative topographic position, will have similar soil profiles, engineering properties, native vegetation and air-photo pattern. Other requirements are that the photographs be of good quality so that stereovision is possible. The pamphlet is well illustrated with photographs and soil maps made from the adjoining photographs.

HARDEN, M. J., "Use of Stereoscopic Methods in Preparing Topographic Maps from Aerial Photographs", Proceedings, 23rd Annual Meeting, Highway Research Board, 1943, pp.552-4

This paper describes the preparation of topographic maps by the multiplex instrument. The process involves the use of aerial photographs to form true scale stereoscopic models of the terrain in which the necessary measurements for position and elevation can be made much more rapidly than similar determinations can be made by survey parties operating in the field. The process has many other advantages not shared by the customary way of making maps in the field and lends itself well to the mapping of areas through which it is proposed to locate new highways, particularly those routed through mountainous regions.

HITTLE, J. E., "The Use of Aerial Photographs in Identifying Granular Deposits and Other Soils", Engineering Bulletin, Purdue University, Vol. XXVII, No. 2, March 1943, pp. 79-86

A general review of the use of aerial photographs in dealing with highway location problems, especially in Indiana. A discussion is given of the means of locating granular deposits by the proper interpretation of information contained on aerial photographs.

HITTLE, JEAN E., "The Application of Aerial Strip Photography to Highway and Airport Engineering", Proceedings, Twenty-sixth Annual Meeting, Highway Research Board, 1946, pp. 226-235

This paper presents a method of gathering pavement performance data by the use of aerial strip photography. This method of aerial photography offers a quick, convenient method of making a permanent record of the essential features of pavement performance that heretofore could only be obtained by visual inspection in the field.

JENKINS, D. S., BELCHER, D. J., GREGG, L. E. and WOODS, K. B., "The Origin, Distribution and Airphoto Identification of United States Soils, with Special Reference to Airport and Highway Engineering", Technical Development Report No. 52, May 1946, 202 pp. and 63 plates, U. S. Dept. of Commerce, Civil Aeronautics Administration

A comprehensive report describing the various soil and material deposits in the U. S. accompanied by a map showing their distribution; and application of the data to airport development.

PARVIS, MERLE, "Development of Drainage Maps from Aerial Photographs", Proceedings, Twenty-sixth Annual Meeting, Highway Research Board, 1946, pp. 150-163

This paper reports the development of techniques for compiling drainage maps of fine detail from aerial photographs of the several counties in Indiana. The air photos used for this work were taken in 1937-1943 in connection with the United States Department of Agriculture map program.

RAUP, HUGH M., "Botanical Problems in Boreal America I and II", The Botanical Review, Vol. 7, No. 3, pp. 148 to 208, March 1941; Vol. 7, No. 4, pp. 209 to 248, April 1941

The author emphasizes the difficulties encountered in attempting to classify forests or to present logical arguments for the existence of a particular plant association in a given location. This paper is principally a review of literature of approximately 250 papers and a statement of the author's opinions of the other investigators' concepts and methods. The paper gives a very technical discussion of the origin and distribution of flora. A short section of the paper is devoted to a discussion of stone polygons. Briefly, in order to have stone polygons, no vegetation can be present during their development. Thus, if both stone polygons and vegetation are present, the vegetative cover is comparatively recent. There is also a discussion of plant

succession. Mapping of vegetation by air photos and the construction of cover type maps from air photos is discussed.

SPURR, STEPHEN H., "Aerial Photographs in Forestry", The Ronald Press Co., New York, 1943

Although the basic theory of the application of photographic techniques to forest inventory was first worked out by European investigators in 1925, Canadian foresters have employed air photos for timber cruising on a large scale since 1929. It was not until World War II that the use of aerial photographs in forestry was seriously undertaken in the United States. This book, written by a forestry professor at Harvard, is intended essentially as a text for advanced forestry students having a knowledge of the fundamentals of silviculture and mensuration. A considerable portion of the publication is devoted to technique and methods of photo-interpretation applicable to forest management which is of interest only to a trained forester. However, chapters on the elements of photogrammetry, techniques and principles of photo-interpretation, and especially a detailed discussion of photography specifications are of definite value to air-photo interpreters in any field.

U. S. GEOLOGICAL SURVEY, "Photo Interpretation of Vegetation in the Tropical Pacific Area and Its Use as an Indicator of Kind of Ground", Engineering Notes No. 20, August 1944, prepared under direction of Office, Chief of Engineers, Military Intelligence Division, Restricted

This paper is a compilation of such information on tropical Pacific forests and cultivated crops as may be of military value, particularly to engineers. The illustrations include aerial photographs of most of the described vegetation types; these are mounted by pairs so that they can be studied under the stereoscope.

WALLACE, ROBERT E., "Cave-In or Thermokarst Lakes in the Nabesna, Chisana, and Tanana River Valleys, Eastern Alaska", Permafrost Program Progress Report No. 4, 1946, U. S. Dept. of Interior, Geological Survey

Report on a study to develop criteria to be used in determining permafrost conditions by means of aerial reconnaissance. The present study of cave-in lakes in the Nabesna, Chisana, and Tanana River valleys of eastern Alaska is part of an investigation of permafrost by the Geological Survey.

WAR DEPARTMENT, "Interpretation of Aerial Photographs", Technical Manual No. 5-246, 31 December 1942, Restricted

The purpose of this chapter is to familiarize the student with the appearance of general terrain features on aerial photographs. This knowledge is essential for all those who use aerial photographs for tactical purposes as well as for the interpreter who studies them to discover information concerning the enemy.

WAR DEPARTMENT, "Aerial Photography Military Applications", War Department Field Manual, FM 30-21, 22 September 1944

The purpose of this manual is to describe in general terms aerial photography and its application to military operations in modern warfare as it relates to air, ground and naval forces. It provides the basic doctrine for the procurement, production, and exploitation of aerial photography.

WOODS, K. B., HETTLE, JEAN E. and FROST, R. E., "Use of Aerial Photos in the Correlation Between Permafrost and Soils", The Military Engineer, Vol. XL, No. 277, November 1948

This article gives a brief discussion of the methods and results obtained in the use of air-photo patterns to identify soils and permafrost for site selection, thus concentrating field reconnaissance on the best sites available. It is based upon three years' field work by Purdue University in Alaska, under contract with the Corps of Engineers, St. Paul District Office.

#### **p. MINING**

CAPPS, STEPHEN R., "The Kantishna Region, Alaska", U. S. Geological Survey Bulletin 687, 1919

This bulletin covers an area bounded by the Alaska Range on the south, the Tanana River on the north, the Nenana River on the east, and the lower Kantishna River on the west; the area lies between the village of Nenana and Mt. McKinley. Field work was done in 1916. The geography and geology of this area were undertaken in 1916 because the Alaska Railroad was being built adjacent to this area, and it was anticipated that mining activity would be greatly increased. Coal as well as gold, silver and antimony was found.

COLLIER, A. J., "Gold Placers of the Seward Peninsula", U. S. Geological Survey Bulletin 328, pp. 40-110, 1908

General introduction to area and history of exploration presented. General outline of physiographic features discussed, i. e., shoreline, mountainous regions, and drainage characteristics. Good report although primarily of a reconnaissance nature. Fairly complete geologic map included.

MERTIE, J. B. JR., "Geology of the Eagle-Circle District, Alaska", Geological Survey Bulletin 816, Dept. of Interior, 1930

This bulletin covers the area along the Yukon River between Circle and Eagle, from Circle upstream to the United States boundary. This bulletin discusses the geography and geology as well as climate and mining in an area which has been very active as a gold mining region since 1897. The work is based on field work by the writer in 1925 and includes references to statements from all prior geology work in this area. It is illustrated with many photographs and diagrams. A very brief reference to permafrost indicates that it has restricted the circulation of the deeper groundwater.

MERTIE, J. B. JR., "Mineral Deposits of the Ruby-Kuskokwim Region,

Alaska", Geological Survey Bulletin 864-C, 1936

This bulletin discusses the geography and geology in connection with the mineral resources of the Ruby-Kuskokwim region in west-central Alaska between the Yukon and Kuskokwim Rivers.

MOFFIT, FRED H., "Geology of the Nutzotin Mountains, Alaska", Geological Survey Bulletin 933-B, 1940, pp. 103-174

This paper deals primarily with the geology of the part of the Nutzotin Mountains extending southeastward from the Nabesna River to Beaver Creek and the boundary between Alaska and the Yukon Territory. This area includes the Nabesna gold mine, on White Mountains, and the Chisana placer-gold district near the head of the Chisana River, both of which have been important producers of gold. The field work represented on the geologic map was partly a revision of work previously done by the writer and others and partly an extension of mapping into areas hitherto unmapped.

MOFFIT, FRED H. and MERTIE, J. B. JR., "The Kotsina-Kuskulana District, Alaska", Geological Survey Bulletin 745, 1923

A geological survey to determine, examine, and map in detail copper-bearing areas which give promise of yielding commercial ores. Survey was made in the Kotsina-Kuskulana district in the part of Alaska known as the Copper River region. It lies at the west end of Chitina Valley on the southwest slope of the Wrangell Mountains.

MOFFIT, F. H., "Geology of the Nome and Grant Central Quadrangles-Alaska", U. S. Geological Survey Bulletin No. 553, pp. 53-54, 1913

Restatement of Tyrrell's description of "Crystosphenes or Buried Sheets of Ice in the Tundra of Northern America".

SMITH, P. S. and MERTIE, J. B. JR., "Geology and Mineral Resources of Northwestern Alaska", U. S. Geological Survey Bulletin 815

Introduction, past and present reports, including discussion of authors' trips, is included. Covers relief and drainage of (1) general features; (2) Koyukuk plateaus; (3) Brooks Range province; (4) Arctic plateaus; and (5) Arctic coastal plain. Description of climate, vegetation, wildlife, and population included. Good topographic and geologic reconnaissance maps of area. Many photos that are of value in description of text.

#### 9. NAVY

DEPARTMENT OF THE NAVY, "Geological Reconnaissance of Maybe Creek -- Ikpihpuk -- Colville River Area, U. S. Naval Petroleum Reserve No. 4, June, July, August 1945, Party No. 3"

This article briefly discusses the difficulties of working areas and recommendations for future work.

DEPARTMENT OF THE NAVY, "Geological Reconnaissance of Sentinel Hill Area, U. S. Naval Petroleum Reserve No. 4, Party No. 1, June, July, August 1945"

This article briefly discusses the plan of work, equipment used, logistics related to moving personnel to and from field, and recommendations as to future work.

**DEPARTMENT OF THE NAVY, "Naval Construction Battalion Detachment 1058, Summary Report on Cold-Weather Operations, Department of the Navy at U. S. Naval Petroleum Reserve No. 4"**

This is a report by S. H. Folk made in February 1946 from information compiled from reports made by various personnel attached to NCBD 1058, covering operations in Naval Petroleum Reserve No. 4 during the winter 1944-45. A Caterpillar D-8 tractor when winterized becomes very satisfactory by increasing the traction by cutting holes in grouser plates to clear packed snow and replace the top carrier rollers with wooden beams to carry the tracks. The weasel is a very effective vehicle for travel over Alaskan arctic terrain. However, the transmissions are too light and the vehicle is not sturdy enough for long cross country trips over rough terrain. There is also a discussion of the operation of bobsleds, wanigans and arctic clothing together with some observations regarding sled-freighting operations.

**DEPARTMENT OF THE NAVY, "Geological Reconnaissance of a Part of the Chandler River, Alaska, U. S. Naval Petroleum Reserve No. 4, Party No. 5, August-September 1945"**

Discusses equipment and methods used in doing ground geological work. Includes a description of the area. It is pointed out that aerial photography, preferably vertical, affords great assistance in this type of work.

**DEPARTMENT OF THE NAVY, "Geological Reconnaissance of Ninuluk -- Prince Creek Areas, U. S. Naval Petroleum Reserve No. 4, Party No. 4, June, July, August 1945"**

Discusses equipment and methods used in doing ground geological work. Includes a description of the area. It is pointed out that aerial photography, preferably vertical, affords great assistance in this type of work.

**DIRECTORATE OF ENGINEER DEVELOPMENT, "Report on Snow and Ice Data", Dept. of National Defense, Ottawa, Canada**

This article deals principally with snow and ice as a function of hauling and sleigh roads. Describes the various types of snow and ice roads with a discussion of maintenance and construction methods. Also discusses the fundamentals of construction and survey. Part I discusses briefly construction and maintenance of winter roads; Part II discusses preparation and maintenance of airfields in winter; Part III discusses ice as a winter highway; Part IV discusses use of explosives in blasting ice, particularly ice jams.

**FAGIN, K. MARSHALL, "Petroleum Development in Alaska", from The Petroleum Engineer for August, September, October, and December 1947**

A series of articles on the Navy's exploration for oil in Naval Petroleum Reserve No. 4. Articles entitled:

1. Oil Prospecting in Alaska
2. Exploration in Alaska
3. Drilling Problems in Alaska
4. Economics of Alaskan Exploration.

These articles contain valuable information regarding the area north of the Brooks Range.

FORAN, WILLIAM T., Lt. Comdr., CEC, USNR, "Geological and Geophysical Report Concerning the Potential Oil Possibilities of the Umiat and Cape Simpson Areas of Naval Petroleum Reserve No. 4 in Northern Alaska", May-September 1945

Discusses aerial photography, electrical surveys at Umiat Well No. 1 and Simpson Core Hole No. 11, temperature survey at Umiat.

HUNT, RALPH W., Capt., CE, "Report of Operation Nanook", Arctic Research Section, The Engineer School, Fort Belvoir, Va., December 1946

This report is a detailed account of an arctic expedition conducted by Navy Task Force 68 in which Army, Coast Guard, Weather Bureau and other personnel participated to obtain military and scientific information for use in planning future polar operations. Operations were conducted in the eastern Canadian Archipelago and at North Star Bay in northwest Greenland near the village of Thule. The report is liberally illustrated with maps and photographs. In connection with the operations conducted, reference is made to the permanently frozen soil beneath an active layer of surface soil.

MARTI, E. J., Lt., USNR, "Operations Report, Seismograph Exploration in Naval Petroleum Reserve No. 4, Alaska, June to September 1945", Department of the Navy

This article discusses equipment and methods of operation of a seismograph party operating in Naval Petroleum Reserve No. 4. Recommendations as to modifications for future work are included.

#### r. PHYSICS AND CHEMISTRY

ANDERSON, A.E.C., FLETCHER, J. E., and EDLEFSEN, N. E., "Soil-Moisture Conditions and Phenomena in Frozen Soils", Transactions, American Geophysical Union, Pt. 2, pp. 356-371, November 1942

A theoretical discussion of experimental methods of measuring the temperature at which soil moisture freezes; interrelations among the thermodynamic variables of state under different conditions of freezing soil moisture; generalized treatment of the effect of pressure on the freezing point, and its application to relatively moist soils -- generalized Clausius-Clapeyron equation; and movement of soil moisture in relation to freezing phenomena in soils. Bibliography.

ANDERSON, J. G., "Solifluction, A Component of Subaerial Denudation", Journal of Geology, Vol. 14, No. 2, pp. 91-112, February-March 1906

Description of and climatic features which cause the slow moving of soil from higher to lower ground by solifluction (derived from solum -- "soil" and fluere -- "to flow") in the subglacial climate of the Falkland Islands, the Rocky Mountains, Spitzbergen and Scandinavia.

ATKINSON, H. B. and BAY, C. E., "Some Factors Affecting Frost Penetration", Transactions, American Geophysical Union, Pt. 3, pp. 935-947, 1940  
Results of field experimental study to determine the effect of depth and density of snow cover and depth of straw cover on depth of frost penetration in plots of ground. Control plots were kept free of snow.

BAVER, L. D., "Soil Physics", pp. 153-155 and 275-289, New York, John Wiley and Sons, 1940, 370 pp.

Discussion of effect of freezing and thawing on soil aggregation; relation of soil color to temperature; thermal properties of soils (specific heat, thermal conductivity, heat capacity, thermal diffusivity); theory of heat flow; soil factors affecting heat conductance; and daily and seasonal changes in soil temperature. Bibliography.

BERGGREN, W. P., "Prediction of Temperature Distribution in Frozen Soils", Transactions, American Geophysical Union, Pt. 3, pp. 71-77, 1943  
Theoretical analysis of temperature distribution in frozen soils. Included are: analysis of an idealized system, solution of examples, and special adaptations of the analysis.

BODMAN, G. B. and DAY, P. R., "Thermoelectric Method of Determining the Freezing Points of Soils", Proceedings, Soil Science Society of America, Vol. 2, pp. 65-71, 1937

The authors state objections to the commonly used method of determining freezing points of soils by means of the Beckman thermometer and describe equipment for thermoelectric measurement of freezing points. Experimental data on the effect of precooling temperatures on the freezing point and data on freezing point depression--moisture content relationships are given.

BOUYOUCOS, G. J., "Classification and Measurement of the Different Forms of Water in Soil by Means of the Dilatometer Method", Michigan Agricultural College, Experiment Station, Technical Bulletin No. 36, September 1917, 48 pp.

The author discusses the principle of the dilatometer method, and its use in determining the relative amounts of free capillary adsorbed, and combined water; describes the apparatus (dilatometer) and procedure used; and presents experimental data giving the per cent unfreezable water at various temperatures for different soils. He also presents data showing volume-change, temperature relationships; the effect of salts on the amount of freezable water; and the relationship between texture and unfreezable water.

BOUYOUCOS, G. J. and MCCOOL, M. M., "Further Studies on the Freezing Point Lowering of Soils", Michigan Agricultural College, Experiment Station, Technical Bulletin No. 31, November 1916, 51 pp.

A test method and procedure, and the principle of that method of determination of freezing point lowering of soils is discussed, and experimental data are presented. The author discusses the relation between freezing point and weight of solid matter and osmotic pressure; significance of unfree water on determinations; and the effect of successive freezings on lowering the freezing point of soil.

BOUYOUCOS, G. J. and MCCOOL, M. M., "The Correct Explanation for the Heaving of Soils, Plants and Pavements", Journal of the American Society of Agronomy, Vol. 20, No. 5, pp. 480-491, May 1928

Three different types of heaving are described and an explanation of the causes of 'soil' heaving is given. The formation of ice crystals and the movement of soil moisture associated with crystal formation are discussed.

BOUYOUCOS, G. J., "Movement of Soils Moisture from Small Capillaries to the Large Capillaries of the Soil Upon Freezing", Journal of Agricultural Research, Vol. 24, No. 5, pp. 427-431, 5 May 1923

The author presents data showing the effect of alternate freezing, thawing, stirring and standing on the freezing point depression of soils. From the data, he arrives at a hypothesis on the movement of moisture from the small to the large capillaries.

BRIDGEMAN, P. W., "Effect of Pressure on the Freezing Point of Water", Smithsonian Physical Tables, Smithsonian Miscellaneous Collections, Vol. 71, p. 200, 1921

Table showing the "Effect of Pressure on the Freezing Point of Water".

CARSLAW, H. S., "Introduction to the Mathematical Theory of the Conduction of Heat in Solids", Dover Publications, New York, 1945

Includes a discussion of all the important boundary problems associated with the equation of conduction. In Chapter I the differential equation of conduction is obtained and some general theorems as to its solution are established. Chapter II deals with Fourier's ring. The next 2 chapters are devoted to linear flow. Chapters V and VI deal with 2-dimensional problems and flow of heat in a rectangular parallelepiped, Chapter VII deals with the circular cylinder, Chapter VIII with the sphere and cone, Chapter IX with sources and sinks, and Chapter X with Green's functions. Chapter XI deals with the use of contour integrals in the solution of the equation of conductance, and Chapter XII deals with the use of integral equations in the solution of the equation of conductance.

JAKOB, M. and HAWKINS, GEORGE A., "Elements of Heat Transfer and Insulation", John Wiley and Sons, New York, 1942

This book discusses three kinds of heat transfer; conduction, convection, and radiation, separately first and in combinations. A chapter is devoted to the basic property of thermal conductivity with particular attention to practical insulations. Unsteady state equations are made clear to the student by some graphical representations. Dimensional analysis is dealt with in the most elementary manner. Some applications of heat transfer in experimental engineering and the interdependence of heat transfer and surface friction form the subject of the last three chapters.

SCHACK, ALFRED, "Industrial Heat Transfer", John Wiley and Sons, Inc., New York, 1933 (Translated from the German by Hans Goldschmidt, Dr.-Ing. and Everett P. Partridge, Ph.D.)

This book discusses (a) The three ways in which heat is transferred and the surface conductance; (b) Analysis of the three mechanisms for heat transfer; (c) Calculations for heat exchangers; (d) Heat transfer in industrial furnaces; (e) Heat transmission and pressure drop; (f) Numerical examples in heat transfer; (g) Compilation of the most important equations for heat transfer; and (h) Important physical constants for heat transfer.

#### s. RAILROADS

BESKOW, GUNNAR, "Soil Freezing and Frost Heaving with Special Application to Roads and Railroads", The Swedish Geological Society, Series C, No. 375, 26th Year Book No. 3 -- Translated by J. O. Osterberg. Published by the Technological Institute, Northwestern University, Evanston, Ill., November 1947

Dr. Gunnar Beskow has devoted most of his life to the study of frost action of soils. This publication is a summary of his studies of the subject up to 1935 and is perhaps the only complete treatise on frost action. It contains a historical introduction and discussions of the structure of frozen soil, the process of soil freezing, heaving caused by the freezing of water in the soil or suction of water to the frost line, capillarity, permeability, groundwater, ground temperatures, and calculation of frost depth in soils.

CAPPS, STEPHEN R., "Geology of the Alaska Railroad Region", U. S. Geological Survey Bulletin 907, 1940

Describes geology and geography of area 140 miles wide and 450 miles long from north to south reaching from Gulf of Alaska northward into Yukon basin. Includes illustrations and maps.

HELL, E.M.M., Chief Engineer, "Memo Re Perpetually Frozen Subsoil Observations in the Vicinity of the Hudson Bay Railway", Canadian National Railways, Winnipeg, Manitoba, Canada, 29 March 1940

This article deals with perpetually frozen subsoil in the regions of the Province of Manitoba principally encountered during

construction of a railway. It is pointed out that the southern boundary of permafrost exists somewhere between latitude 54°30' and 55°0' in Manitoba. Permafrost in this area may exist in the form of islands. North of 56°30' latitude, permafrost and tundra vegetation are continuous. There is a table showing thickness of permafrost in various parts of Manitoba, Northwest Territory, and the Yukon Territory.

#### t. REFRIGERATION

CARPENTER, MARTIN R., "Building Ice Skating Rinks", Refrigerating Engineering, Vol. 21, p. 334, May 1931

This article discusses various design and operating factors including cooling loads for winter and summer.

HERTER, CHARLES H., "Design of Ice Skating Rinks", Heating and Ventilating, Vol. 43, No. 4, April 1946, pp. 57-62

This article reviews the construction features of some rinks, analyzes operating expenses, and financial returns, presents data of value to those interested in ice skating rink design.

REFRIGERATING DATA BOOK, "Storage Below 32°F", American Society of Refrigerating Engineers, 1943, p. 174

A short article including a table on latent heat of freezing load and a table on conductivity of insulating materials.

REFRIGERATING DATA BOOK, "Chapter 20 -- Evaporators and Freezing Systems", American Society of Refrigerating Engineers, 1940, pp. 279-284

This chapter deals with various types of evaporators and freezing systems and discusses the design of the heat transfer equipment. Numerous tables give information such as the linear feet of 1-1/4-in. pipe per ton of ice making capacity and the theoretical length of pipe circuit and other similar information needed in the design of heat transfer equipment. Other parts of this data book deal with refrigeration cycles, fundamental data, industrial systems, domestic and commercial systems and air conditioning systems. Chapter 11 deals with load calculations.

#### u. ROADS AND TRANSPORTATION

AARON, HENRY, "Frost Heave in Highways and Its Prevention", Public Roads, Vol. 15, No. 1, pp. 10-25, March 1934

Soil profiles in which frost heave has been observed, and subgrade, base and drainage designs which have been used to prevent frost heave are discussed and illustrated.

ALASKAN DEPARTMENT (J. S. Army, Alaska), "Reconnaissance to Determine Feasibility of Winter Operation of the Richardson Highway in Alaska", 20 December 1943

An informal report on the feasibility of keeping the Richardson Highway open for freighting operations during the winter season,

the problems to be encountered in such an undertaking, and the considerations involved, from an engineering standpoint.

BEKKER, M. G., "Fundamentals of Soil Action Under Vehicles", Part Two, Technical Memorandum No. 8, National Research Council of Canada, Associate Committee on Soil and Snow Mechanics, Ottawa, Canada, June 1947

This paper presents a mathematical analysis of the stability of a model representing wheel or track of a moving vehicle. The proposed method of determining a trafficability curve is based on accepted theories of soil mechanics and represents a continuation of the work described in Technical Memo No. 6. A cohesionless medium and the stability of a single wheel or a single track shoe with or without grouser is alone considered. The proposed method, however, is general in scope, and may be easily extended over cohesive soils and several wheels and shoes.

BESKOW, GUNNAR, "Soil Freezing and Frost Heaving with Special Application to Roads and Railroads", The Swedish Geological Society, Series C, No. 375, 26th Year Book No. 3 -- Translated by J. O. Osterberg. Published by the Technological Institute, Northwestern University, Evanston, Ill., November 1947

Dr. Gunnar Beskow has devoted most of his life to the study of frost action of soils. This publication is a summary of his studies of the subject up to 1935 and is perhaps the only complete treatise on frost action. It contains a historical introduction and discussions of the structure of frozen soil, the process of soil freezing, heaving caused by the freezing of water in the soil or suction of water to the frost line, capillarity, permeability, groundwater, ground temperatures, and calculation of frost depth in soils.

BOUYOUCOS, G. J. and MCCOOL, M. M., "The Correct Explanation for the Heaving of Soils, Plants and Pavements", Journal of the American Society of Agronomy, Vol. 20, No. 5, pp. 480-491, May 1928

Three different types of heaving are described and an explanation of the causes of frost heaving is given. The formation of ice crystals and the movement of soil moisture associated with crystal formation are discussed.

BURTON, VICTOR R., "Application of Soil Science to Highway Engineering", Roads and Streets, Vol. 71, No. 5, pp. 163-5, May 1931

General discussion of correction, prevention of heaves and treatment of boils. Includes illustrations showing location of frost action area with respect to soil profile.

CASAGRANDE, L., "Lessons from Frost Damage to Roads", Roads and Bridges, (Canada), Vol. 60, No. 2, p. 100, February 1942

An abstract of Casagrande, L. "What has the Frost Damage of Last Winter Taught Us", Strasse, 1940 7(9/10) 193-201.

CLARK, K. A., "Some Examples of Frost Boils Occurring on Alberta

Highways", Canadian Engineer, Vol. 69, No. 11, pp. 7-10, 10 September 1935

A discussion of the physics of frost heaving; the conditions under which heaving does not occur; the relation of soil classification type to heaving; and a description of frost boil occurrences with illustrations of soil profiles in which frost boils occur.

CLARK, A. C., "The Alaska Highway -- Effect of Climate and Soils on Design", Civil Engineering, Vol. 13, No. 5, May 1943, pp. 209 to 212; Western Construction News, Vol. 18, March 1943, pp. 105 to 109

This paper explains the unusual soil and climatic conditions that were encountered during construction of the pioneer road for the Alaska Highway and their effect on design. It discusses the difficulties encountered in construction on permanently frozen ground or ice close to the surface immediately under a heavy insulating layer of moss or grasses; on layers of ice and frozen soil occurring at depths of 3 ft or more; and where an ice condition known as "glaciering" exists. Includes several photos.

EAGER, W. L. and FRYOR, W. T., "Ice Formation on the Alaska Highway", Public Roads, Vol. 24, No. 3, pp. 55-74, January-February-March 1945

A treatise on the formation of surface ice. Includes discussion of factors associated with icing and methods to prevent or reduce icing on new construction.

ENGINEERING NEWS-RECORD, "Mitigating Frost Action on Road Surface", Engineering News-Record, Vol. 104, pp. 1021-1023, 19 June 1930

A staff review of and extracts from the report of the Committee on Subgrades and Pavement Bases, 1930 convention of the American Road Builders Association. Discussed are: surface damage from freezing and thawing; granular sub-bases; and drains and backfilled trenches.

ENGINEERING NEWS-RECORD, "Building the Alaska Highway", Vol. 129, No. 12, 17 September 1942, pp. 4-5

A short article on the construction of a pioneer road for the Alaska Highway. Includes several photos of the road, bridges and contractors' camps.

ENO, F. H., "The Influence of Climate on the Building, Maintenance and Use of Roads in the United States", Highway Research Board Proceedings, Vol. 9, pp. 216-223, 1929

Charted maps of the U. S. giving winter temperature data and suggestions for research on frost action.

ENO, F. H., "Some Effects of Soil, Water and Climate Upon the Construction, Life, and Maintenance of Highways", Ohio State University, Engineering Experiment Station Bulletin No. 85, pp. 57-60, November 1934

Brief discussion of capillarity and frost action in subdrainage of highways in Ohio.

HEADQUARTERS, 925th ENGINEER AVIATION GROUP, "Roads and

Highways in Alaska", Part I, The Spring Thaw, 30 June 1948, Fort Richardson, Alaska; Part II, The Summer Season, September 1948

Reconnaissance teams from the Headquarters, 925th Engineer Aviation Group, 807th Engineer Aviation Battalion, and the 813th Engineer Aviation Battalion, began gathering information concerning conditions of roads and highways in Alaska during the spring thaw of 1948 on 1 April. Information was obtained from actual observations made during 5100 miles of traveling in Alaska. In general, conditions of the roads throughout Alaska were found to be very good. However, there were sections of the road that were impassable at times. The worst piece of road was found on the Palmer Highway connecting Anchorage and Palmer. The second poorest stretch of road in Alaska was the road between Fairbanks and Eielson Air Force Base. The following highways were investigated: Palmer, Glenn, Richardson (Valdez to Gulkana), Richardson (Gulkana to Big Delta), Richardson (Big Delta to Fairbanks), Slana-Tok, Alaska, and Edgerton Cutoff, Steese Highway and Elliott Highway. This report is illustrated with excellent pictures showing the methods used in taking care of icing and other work necessary in Alaska to maintain traffic.

JOHNSTON, R. W., "Speeding up the Alaska Highway by Aerial-Survey Methods", Roads and Bridges, Vol. 80, No. 11, p. 17, November 1942

Brief coverage of the planning, location, construction, and economics of the Alaska Highway. Army's task to construct road from location to actual construction. Schedule set for completion. Aerial surveys aided in location when work began to lag behind schedule. Air surveys were used to locate gravel deposits when needed, and access roads were built to them.

MAIERSPERGER, WALTER P., Major, Air Corps, Technical Observer, "Canadian Winter Exercise 'Musk-Ox'", 1946 October, Air Materiel Command, Wright Field, Dayton, Ohio, Confidential

Exercise Musk-Ox was a movement of ground vehicles supported entirely by air. It has as its objective three broad subjects: (1) Air Force cooperation in the Arctic; (2) Evaluation of over-snow vehicles under winter conditions; and (3) Certain technical and scientific research projects in the Arctic.

MILLER, H. H. and SMITH, D. N., "Prevention of Frost Heaving in Roads", Roads and Streets, Vol. 78, No. 8, pp. 273-4, August 1935

A review of the author's report in Roads and Streets, Vol. 77, No. 6, pp. 219-221, June 1934, and description of additional experimental test sections to determine the effectiveness of treatments of existing heaves by drilling holes through the surface and backfilling with calcium chloride and gravel. Includes cost data on drilling holes.

MILLER, H. H. and SMITH, D. N., "Methods for Prevention of Road Failures Due to Frost", Roads and Streets, Vol. 77, No. 6, pp. 219-221, June 1934

This article presents a plan for correcting frost heaves in

roads in service by digging 1-ft-diameter by 2-ft-deep holes at 4- to 8-ft centers in the road and backfilling with pea gravel and calcium chloride. Good results are claimed.

MONTGOMERY, R. H., "Precise Levelling on the Alaska Highway", Transactions, American Geophysical Union, Vol. 29, No. 1, February 1948, Published by National Research Council of National Academy of Sciences, Washington, D. C.

This paper presents the history of precise vertical control in Alaska and the Yukon; discusses particular problems encountered in bench-mark construction and description when working in the northern latitudes; and comments on the evidence indicating regional earth movement.

MORIARTY, C., "So You Think You Have Transportation Problems", Pacific Builder and Engineer, Vol. 51, No. 5, May 1945, pp. 52-55

How Lytle and Green moved equipment, supplies and men to CAA project sites in the primitive Alaskan interior despite some of world's toughest natural barriers of weather, water and terrain.

MORTON, JOHN D., "The Application of Soil Mechanics to Highway Foundation Engineering", Proceedings, International Conference on Soil Mechanics and Foundation Engineering, Harvard University, Vol. 1, pp. 243-7, 22-26 June 1936

Discussed are: frost heaving as related to the various soil groups of the New Hampshire State Highway Department and Public Roads Administration soil classification systems; the use of the soil survey in locating frost-susceptible soils and soil conditions; providing data for design of subsurface drainage systems, and locating base materials, etc. Typical sections of the New Hampshire, S.H.D. soil profile showing information as it is presented to design and construction engineers are included.

PUBLIC WORKS MAGAZINE, "Preventing Spring Breakup of Roads", Public Works Magazine, Vol. 75, No. 8, p. 18, August 1944

Description of a method of introducing calcium chloride into holes in the subgrade to prevent spring breakup.

RICHARDSON, HAROLD W., "Alcan -- America's Glory Road", Engineering News-Record, Vol. 129, No. 25, 17 December 1942, pp. 83-96

Part I -- Strategy and Location. This is the first of a series of three articles on the Alcan Highway. This article tells of the purpose of the project and describes the route location. With regard to permafrost, the following is quoted from the article: "Other troops, working in the northern sector of the highway, learned to leave permanently frozen ground alone. They learned from experience it was best to leave the humus in place as insulation, to cover it up with brush and trees cleared from the site, then fill over the whole for the road." Included are numerous photos and a map of the route of the highway.

"Alcan -- America's Glory Road", Engineering News-Record, Vol. 129,

No. 27, 31 December 1942, pp. 35-42

Part II -- Supply, Equipment and Camps. This is the second of the Alcan Highway series. This article tells of the problems of supply, how equipment, materials and supplies were gotten into the wilderness and distributed throughout the project. Also describes living and working conditions of the road camps and headquarters, and the difficult equipment repair and maintenance problems. Includes numerous photos of equipment and camps, and one photo of the permanently frozen ground.

"Alcan -- America's Glory Road", Engineering News-Record, Vol. 130, No. 2, 14 January 1943, pp. 131-138

Part III -- Construction Tactics. This is the third and concluding article of the Alcan Highway series. This article describes actual construction operations, how the Army put the various regiments on the project and attacked the work, how the contractors worked, and how the bridge and drainage problems were solved. Includes photographs and a map of the route of the highway.

RICHARDSON, HAROLD W., "Alcan Highway Diary", Engineering News-Record, Vol. 129, No. 21, 19 December 1942, pp. 54-55

The following is quoted from Mr. Richardson's diary with regard to permafrost: "Whitehorse, Y. T. .... Oct. 21, 1942. .... Interesting construction over perpetually frozen ground. Permanent frost here is 12 in. below surface. Rather than try to disturb it, the procedure is to leave the moss and humus in place, fell the trees and brush across the line as further insulation, then fill for the road on top of the brush and trees. Difficult to find enough unfrozen material for fill, but they are getting most of it out of slide banks and side-hill cuts."

RUCKLI, ROBERT, DR., "Frost Damage in Highway Subgrades", Strasse und Verkehr, Vol. 29, No. 19, pp. 311-318; No. 20, pp. 332-9; No. 21, pp. 343-353; No. 22, pp. 357-64; No. 24, pp. 388-96; No. 25, pp. 397-402; 1943 (Translated by H. B. Edwards, Engineer Dept. Research Center, U. S. Waterways Experiment Station, Vicksburg, Miss., August 1944)

A long and informative article arranged in 7 parts. (1) Types of ice in soil; (2) The mechanics of frost heaving; (3) Frost conditions in Switzerland; (4) Temperature conditions in the soil; (5) Frost penetration in the soil; (6) Theory of frost heaving; and (7) Field experiments.

SOURWINE, J. A., "A Method of Analysis of Data on Frost Occurrence for use in Highway Design", Public Roads, Vol. 11, No. 3, May 1930, pp. 51-60

A statistical study of intensity duration and frequency of low temperature occurrence over a period of years and a suggested method by which climatological records may serve as a guide in the determination of probable ground freezing occurrence. Discusses: source of data; suitability of absolute minimum temperatures; critical air temperature for ground freezing; critical depth of freezing; critical soil temperature for freezing; relation between minimum temperature in air and in soil; frequency of minimum temperatures; critical value of lowest monthly average of daily

minimum temperature; effect of precipitation; and effect of duration of cold.

SPINDLER, W. H., "Drainage on the Alaska Highway", Roads and Bridges, Vol. 82, No. 1, January 1944

General discussion of drainage problems encountered on Alaska Highway. Drainage characteristics not known and control was based on judgment. Errors were corrected in the following year. "Glaciers" on rivers caused problems (MacDonald Creek "glacier" covered the bridge spanning it). Tundra and moss restricted runoff; gravels, glacial fans allowed seepage and posed no drainage problems. Seepage particularly bad on sidehills where it is likely to cause landslides and road failures along with "glaciers". Many original bridges were only temporary structures that were to be replaced. A few permanent structures were built.

SPINDLER, W. H., "Second Year of Building the Alaska Military Highway"; "Drainage Problems on the Alaska Highway"; "Convoy to Alaska"; The Highway Magazine, November-December 1943, Vol. XXXIV

An interesting discussion of construction of the Alaska Highway showing the problems encountered but very little on permafrost. Drainage problems are the principal items of interest. Notes about traffic using Alaska Highway and what tourists may expect.

STURDEVANT, CLARENCE L., Brig. Gen., "U. S. Army's First Official Story of the Alaskan Highway", Roads and Bridges, Vol. 81, No. 3, March 1943

A general over-all picture of U. S. Army operations on the Alaska Highway. Some details as to methods, equipment, and personnel used are covered. Many photographs and a few sketch maps used to show progress.

TABER, STEPHEN, "Freezing and Thawing of Soils as Factors in the Destruction of Road Pavements", Public Roads, Vol. 11, No. 6, August 1930, pp. 113-132

A summary of Taber's comprehensive studies of frost action in soils. Apparatus and test methods are described. Freezing effects in closed and open systems; direction of growth of ice crystals; grain size; soil composition; water supply; rate of cooling; effect of load pressure; the mechanics of frost heaving in open systems; and freezing and thawing of soils under pavements are discussed.

TABER, STEPHEN, "Some Problems of Road Construction and Maintenance in Alaska", Public Roads, Vol. 23, No. 9, pp. 247-251, July-August 1943

Origin, extent and description of perennially frozen ground and a review of the author's theory of segregation of water in the form of ice during freezing of soils.

WAR DEPARTMENT, "Construction of Runways, Roads and Buildings on Permanently Frozen Ground", Technical Bulletin TB 5-255-3, January 1945

Discusses methods and equipment in detail.

WILLIAMS, G. A., "Winter-Maintenance Problems on the Alaska Highway", Roads and Bridges, Vol. 81, November 1943, pp. 27-30, 58-59

WILSON, T. T., "Methods and Equipment Used to Keep Manitoba's Roads Open in Winter", Engineering and Contract Record, Vol. 57, 9 August 1944, pp. 28, 29 and 48

WINN, H. F., "Frost Action in Highway Subgrades and Bases", Proceedings, Purdue Conference on Soil Mechanics and Its Applications, Purdue University, Symposium on Frost Action, pp. 444-457, 2-6 September 1940  
Review of findings of previous investigations and theory of ice segregation. Also results of laboratory studies on frost action in treated and stabilized bases and a discussion of means of preventing frost action. Discussions by Morton, Tremper and Stokstad. Selected bibliography.

#### V. SEWAGE DISPOSAL

FARRELL, J. W. B., "Winter Precautions at Regina, Saskatchewan", Water Works Engineering, Vol. 98, 26 December 1945, pp. 1501-20

This article discusses the problems of water works maintenance at Regina.

HURST, W. D., "How Winter Problems are Handled at Winnipeg, Canada", Water Works Engineering, Vol. 98, No. 25, 12 December 1945

This article discusses water works maintenance at Winnipeg. Author points out trouble developed with one type of hydrant because condensation moisture collected beneath operating nut and froze onto its bearing. Other operating experiences recounted.

ROCHE, M. A. and MITCHELL, M. R. C., "Water Works and Sewage in the Far North", Public Works Magazine, August 1948, pp. 21-23

A. Unusual Distribution System at Flin Flon, Manitoba, by M. A. Roche. Permanent frost exists here between 1 and 16 ft below the surface. Water pumped through 13,600 ft of 20-in. woodstave pipe has not frozen in 18 years. Heating required on one occasion. Storage tanks and utilidors for distribution are steam heated. Distribution lines are in 4000-ft circuits in which water is circulated continuously. Steam is used to hold temperature at not less than 38° F.  
B. Water and Sewerage at Sherridon, Manitoba, by M.R.C. Mitchell. Water mains and sewers are laid close together in trenches about 8 ft below the ground surface or together with steam pipes on the surface in wooden boxes packed with sawdust. The water mains are discharged into the dead ends of sewers to prevent freezing. Sewers laid in boxes are cast iron pipe and those buried in the ground are vitrified clay. The cost of heating the pipes in the boxes is quite high. Boxes inclosing pipes in general are large enough to permit a man to

work inside without opening the box from the outside.

#### W. SOILS INCLUDING GROUND TEMPERATURE

AARON, HENRY, "Frost Heave in Highways and Its Prevention", Public Roads, Vol. 15, No. 1, March 1934, pp. 10-25

Soil profiles in which frost heave has been observed and sub-grade, base and drainage designs have been used to prevent frost heave are discussed and illustrated.

ABBE, C., "Ice Columns in Gravelly Soil", U. S. Dept. of Agriculture, Weather Bureau, Monthly Weather Review, Vol. 33, No. 4, pp. 157-8, April 1905

Description and explanation of the phenomenon of slender columns of ice (needle ice, hoar frost) found at the surface of gravelly soil in moist places after a clear, cool night.

ALLEN, HAROLD, "Report of Committee on Warping of Concrete Pavements", Proceedings, Highway Research Board, Vol. 25, pp. 199-250, 1945

A description of concrete pavement details and their relation to distortion of pavement (high joints) due to frost action; artificially produced high joints; joint drains; oil and tar treated sub-grades; selected low volume change base courses and maintenance of joints as related to frost action and high joints.

ALLEN, HAROLD and JOHNSON, A. W., "The Results of Tests to Determine the Expansive Properties of Soils", Proceedings, Highway Research Board, Vol. 16, pp. 220-233, 1936

Condensed report of a comprehensive study of the swelling characteristics of five Kansas soils. Includes data on volume change on repeated freezing and thawing on soil.

AMERICAN SOCIETY FOR TESTING MATERIALS, "Procedures for Testing Soils", September 1944, 260 S. Broad St., Philadelphia, Pa.

This publication brings together in convenient form various methods of testing soils now in current use. Included are 13 methods adopted as Standard or Tentative Standard by the American Society for Testing Materials, and 38 suggested methods of test for soil and soil mixtures. The suggested methods have no official status in the Society. They represent available test procedures that have been used with some degree of success for the determinations in question and are presented in this publication only as information. The soil test procedures fall into 5 categories each pertaining to a particular type of soil testing as follows: Part I -- Indicator Tests on Soils; Part II -- Compaction and Consolidation Tests on Soils; Part III -- Strength Tests on Soils; Part IV -- Tests for Soil-Cement; and Part V -- Tests for Soil-Bituminous Mixtures.

ANDERSON, A. B. C., FLETCHER, J. E. and EDLEFSSEN, N. E., "Soil-Moisture Conditions and Phenomena in Frozen Soils", Transactions, American Geophysical Union, Pt. 2, pp. 356-371, 1942

A theoretical discussion of experimental methods of measuring the temperature at which soil moisture freezes; interrelations among the thermodynamic variables of state under different conditions of freezing soil moisture; generalized treatment of the effect of pressure on the freezing point, and its application to relatively moist soils -- generalized Clausius-Clapeyron equation; and movement of soil moisture in relation to freezing phenomena in soils. Bibliography.

ARMCO CULVERT MANUFACTURERS ASSOCIATION, "Handbook of Culvert and Drainage Practice", pp. 41, 67, 111, 305-8, and 331, 1937. R. R. Donnelley and Sons, Chicago

Pressure due to frost action, transverse forces and frost action, depth of footings, frost heaves and frost boils, heaving track, and theory of frost heaving.

ARNDT, W. J., "Temperature Changes and Duration of High and Low Temperatures in a Concrete Pavement", Proceedings, Highway Research Board, Vol. 23, pp. 273-9, 1943

Includes data on soil temperatures under concrete pavements for the period 1936-1941.

ARNOLD, F. P., "Frost Breaks in Macadam Roads Due to Inadequate Drainage", Engineering News-Record, Vol. 79, No. 20, p. 933, 15 November 1917

Results of a field study of 96 bituminous macadam failure areas in Wyoming County, N. Y. The drainage conditions causing failure due to frost action and the suggested remedial measures are described.

ATKINSON, H. B. and BAY, C. E., "Some Factors Affecting Frost Penetration", Transactions, American Geophysical Union, Pt. 3, pp. 935-747, 1940

Results of field experimental study to determine the effect of depth and density of snow cover and depth of straw cover on depth of frost penetration on plots of ground. Control plots were kept free of snow.

BARNES, H. T., "Ice Formation", 260 pp., 1906, 1st Edition, John Wiley and Sons, New York

A treatise on the formation of ice. This reference pertains to that part of the text which deals with the theory of the formation of ice in water, and the formation of frazil ice (masses of spicule ice in flowing streams) and anchor ice (ice anchored to the bottoms of streams).

BARNES, LYNN C., "Permafrost: A Challenge to Engineers" Military Engineer, Vol. 38, January 1946, pp 9-11

This article gives a brief discussion on permafrost regions, thermal regime, as well as discussion of the permafrost project assigned to St. Paul District by the Corps of Engineers, Dept. of the Army. Discusses briefly the investigations and tests, project objectives, and includes several photographs of natural soil and

ice formations.

BAVER, L. D., "Soil Physics", 370 pp., 1940, John Wiley and Sons  
Discussion of effect of freezing and thawing on soil aggregation;  
relation of soil color to temperature; thermal properties of  
soils (specific heat, thermal conductivity, heat capacity, thermal  
diffusivity); theory of heat flow; soil factors affecting heat con-  
ductance; and daily and seasonal changes in soil temperature.  
Bibliography.

BECKER, G. F. and DAY, A. L., "The Linear Force of Growing Crystals",  
Proceedings, Washington Academy of Sciences, Vol. 7, pp. 283-288, July  
1905

The authors found it practicable, in a saturated alum solution  
at a constant temperature, to grow clear crystals a centimeter  
in diameter which would raise a weight of one kilogram a  
distance of several tenths of a millimeter. Similar results  
were obtained with salts of copper, potassium and lead.

BEKKER, M. G., "Fundamentals of Soil Action Under Vehicles", Part Two,  
Technical Memorandum No. 8, National Research Council of Canada, Associ-  
ate Committee on Soil and Snow Mechanics, Ottawa, Canada, June 1947

This paper presents a mathematical analysis of the stability  
of a model representing a wheel or track of a moving vehicle.  
The proposed method of determining a trafficability curve is  
based on accepted theories of soil mechanics and represents  
a continuation of the work described in Technical Memo No. 6.  
A cohesionless medium and the stability of a single wheel or  
a single track shoe with or without grouser is alone considered.  
The proposed method, however, is general in scope, and may be  
easily extended over cohesive soils and several wheels and  
shoes.

BELCHER, D. J., "Subgrade Soil Temperatures", Proceedings, Purdue Con-  
ference on Soil Mechanics and Its Applications, Purdue University, Symposi-  
um on Frost Action, pp. 474-482, 2-6 September 1940

Data on and discussion of influence of air temperatures, propaga-  
tion of temperatures, temperature and frost penetration in soils.

BELCHER, DONALD J., "The Engineering Significance of Soil Patterns",  
Engineering Experiment Station, Purdue University, Lafayette, Ind., De-  
cember 1944, Reprint No. 13 from Proceedings of the Twenty-third Annual  
Meeting, Highway Research Board, November 1943

The term "soil pattern" is used in the comprehensive sense  
that includes not only the color pattern of soils but the numerous  
other factors recorded in an aerial photograph that are influenced  
by the soil. When properly evaluated, they indicate the engineer-  
ing properties of the soil. This work stems, in a large measure,  
from an engineering evaluation of pedology -- the science of soil  
formation -- and its application to the problems of highway design,  
construction, and maintenance. Its subsequent use in airport site  
selection has permitted an analysis of the soil patterns and their

significance in areas existing under a wide range of soil, parent material, and climatic conditions. Inasmuch as pedology is an important phase of photo-interpretation, a simplified form that may be termed engineering pedology is discussed from the standpoint of subgrade problems. A number of extensive soil areas are described in detail and test data showing their uniformity are presented. Photographs of these areas are included to illustrate their respective patterns. The data show that the soil pattern has engineering significance and that it indicates the conditions that affect the location and construction of highways and airports.

BELCHER, D. J., GREGG, L. E. and WOODS, K. B., "The Formation, Distribution and Engineering Characteristics of Soils", Purdue University, Engineering Bulletin (Research Ser. No. 87, Highway Research Bulletin No. 10), pp. 125-132, January 1943

Discussion of frost action and its relation to nature of glacial drift, pedologic soil series, soil structure and to damage occurring during the frost melting period. Bibliography of 214 published works.

BELOTELKIN, K. T., "Soil Freezing and Forest Cover", Transactions, American Geophysical Union, Pt. 1, pp. 173-5, 1941

Depth of and time of soil freezing and rapidity of thawing as related to type of forest cover; effect of snow cover, forest litter, natural internal soil drainage and soil-texture on frost penetration.

BENKELMAN, A. C., "Studies of Frost Heaves in Michigan", Roads and Streets, Vol. 71, No. 7, pp. 272-6, July 1931

A condensed version of papers by Burton and Benkelman, Proceedings, Highway Research Board, Vol. 10, pp. 259-275, 1930 and Benkelman and Olmstead, Proceedings, Highway Research Board, Vol. 11, Pt. 1, pp. 152-165, 1931. Also similar to paper by Benkelman presented at the 17th Annual Conference on Highway Engineering at the University of Michigan, 19 February 1931.

BENKELMAN, A. C. and OLMSTEAD, F. R., "A New Theory of Frost Heaving", Proceedings, Highway Research Board, Vol. 11, Pt. 1, pp. 152-165, 1931

A new hypothesis on the mechanics of frost heaving based upon a fluctuating frost line.

BENKELMAN, A. C. and OLMSTEAD, F. R., "The Cooperative Project on Structural Design of Non-Rigid Pavements", Proceedings, Highway Research Board, Vol. 26, pp. 13-25, 1946

Progress report, including data on relationship between weather conditions, moisture content, density and maximum V-L (vertical-lateral pressure in triaxial test) for subgrade soil samples taken under the base course.

BENNETT, E. F., "Frost Action in Soils", Proceedings, Purdue Conference on Soil Mechanics and Its Applications, Purdue University, Symposium on Frost Action, pp. 471-3, 2-6 September 1940

Discussion on frost heave around culverts, drainage and the use of the soil survey for locating frost-susceptible soils and soil conditions.

BERGGREN, W. P., "Prediction of Temperature Distribution in Frozen Soils", Transactions, American Geophysical Union, Pt. 3, pp. 71-77, 1943

Theoretical analysis of temperature distribution in frozen soils. Included are: analysis of an idealized system, solution of examples and special adaptations of the analysis.

BESKOW, G., "Prevention of Detrimental Frost Heave in Sweden", Proceedings, Highway Research Board, Vol. 18, Pt. 2, pp. 366-70, 1938

A classification of heave and frost boil characteristics based on type of pavement and a description of measures used to prevent damage by frost. Preventive measures described are the use of insulation and deep drainage. The depth of drains necessary to prevent detrimental frost action; the basis for selecting type of treatment; the use of additives; testing methods; and criteria for susceptibility of soils to frost heaving are discussed.

BESKOW, GUNNAR, "Scandinavian Soil Frost Research of the Past Decade", Highway Research Board, Proceedings of the 27th Annual Meeting, 1947, pp. 372-381

Fundamental research work, dealing with conditions and mechanics of frost heave and frost boils and with methods for preventing and counteracting them (base exchange, isolation, deep drainage, etc.) was completed prior to 1935. A formula was written giving frost-heave speed as a function of load pressure, groundwater depth, and fundamental soil properties; capillarity, permeability, etc. In the past decade (1937-1946) the principal advance in this field has been the result of the comprehensive Norwegian investigation on frost depth as a function of temperature conditions and material properties. The paper describes this work and contemporary Swedish research in frost action. The effect of soil stabilizing chemicals on frost action is reported.

BESKOW, GUNNAR, "Soil Freezing and Frost Heaving with Special Application to Roads and Railroads", The Swedish Geological Society, Series C, No. 375, 26th Year Book No. 3, 1935 -- Translated by J. O. Osterberg. Published by the Technological Institute, Northwestern University, Evanston, Ill., November 1947

Dr. Gunnar Beskow has devoted most of his life to the study of frost action of soils. This publication is a summary of his studies of the subject up to 1935 and is perhaps the only complete treatise on frost action. It contains a historical introduction and discussions of the structure of frozen soil, the process of soil freezing, heaving caused by the freezing of water in the soil or suction of water to the frost line, capillarity,

permeability, groundwater, ground temperatures, and calculation of frost depth in soils.

BETTER ROADS, "Holding Down Spring Thaw Damage", Better Roads, Vol. 17, No. 4, pp. 32-34, April 1947

Answers from 7 state and 2 county highway departments to the Better Roads Forum questions: "How can we diplomatically keep heavy trucks off the roads they will damage most severely? How can we convince truck owners and operators that load restrictions during the breakup period are in everyone's interest?"

BLACK, ROBERT F., "Permafrost Program -- Progress Report No. 2, Permafrost Investigation at Point Spencer, Alaska", U. S. Geological Survey, 1946

Report on an investigation of the regional geologic aspects of permafrost as related to military engineering problems, particularly in regard to selection of airfield sites, so that ultimately criteria can be established for the accurate forecast of the problems and conditions which will be encountered in permafrost areas of possible military interest that are inaccessible to ground reconnaissance. The immediate aim of the investigation at Point Spencer was to determine the geologic and permafrost conditions with special emphasis on groundwater.

BLANCHARD, A. H., "American Highway Engineers Handbook", pp. 450, 451, 923, John Wiley and Sons, New York, 1919

Subdrainage and failures due to frost action.

BODMAN, G. B. and DAY, P. R., "Thermo-electric Method of Determining the Freezing Points of Soils", Proceedings, Soil Science Society of America, Vol. 2, pp. 65-71, 1937

The authors state objections to the commonly used method of determining freezing points of soils by means of the Beckman thermometer and describe equipment for thermoelectric measurement of freezing points. Experimental data on the effect of precooling temperatures on the freezing point and data on freezing point depression-moisture content relationships are given.

BOUYOUCOS, G. J., "An Investigation of Soil Temperatures and Some of the Factors Influencing It", Michigan Agricultural College, Experiment Station, Technical Bulletin No. 17, February 1913, 196 pp.

The results of heat conductivity experiments on natural soils (gravel, sand, loam, clay and peat) and the effect of snow cover on soil temperatures. Also given are data on the freezing point of solutions in sand and on the effect of various admixtures on the rate of rising and lowering of temperatures.

BOUYOUCOS, G. J., "Effect of Temperature on Movement of Water Vapor and Capillary Moisture in Soils", Journal of Agricultural Research, Vol. 5, No. 4, pp. 141-172, 25 October 1915

Test apparatus, test methods, experimental data and theory of movement of moisture from warm soil to cold soil at various

initial moisture contents. Includes data on both vapor movement and capillary movement of moisture and relation of temperature to surface tension and viscosity of water.

BOUYOUCOS, G. J. and MCCOOL, M. M., "The Freezing Point Method as a New Means of Measuring the Concentration of the Soil Solution Directly in the Soil", Michigan Agricultural College, Experiment Station, Technical Bulletin No. 24, December 1915, 44 pp.

A correlation exists between the concentration of the soil solution and the freezing point of the soil. Further discussion is given in Technical Bulletin 31, 1916, by the same authors.

BOUYOUCOS, G. J., "Soil Temperature", Michigan Agricultural College, Experiment Station, Technical Bulletin No. 26, January 1916, 133 pp.

The author reviews his previous work (Technical Bulletin No. 17, 1913) on specific heat and conductivity tests and presents voluminous soil temperature data taken during 1913, 1914 and 1915. He also discusses the effect of meteorological elements on the soil temperature; daily and monthly maximum and minimum temperature, the monthly amplitude, and the degree of amplitude for different depths and the law it follows.

BOUYOUCOS, G. J. and MCCOOL, M. M., "Further Studies on the Freezing Point Lowering of Soils", Michigan Agricultural College, Experiment Station, Technical Bulletin No. 31, November 1916, 51 pp.

A test method and procedure, and the principle of that method of determination of freezing point lowering of soils is discussed, and experimental data are discussed. The author discusses the relation between freezing point and weight of solid matter and osmotic pressure; significance of unfree water on determinations; and the effect of successive freezings on lowering the freezing point of soil.

BOUYOUCOS, G. J., "Measurement of the Inactive or Unfree Moisture in the Soil by Means of the Dilatometer Method", Journal of Agricultural Research, Vol. 3, No. 6, pp. 183-217, 5 February 1917

Two methods (the freezing point and dilatometer methods) are presented for determining the freezing point of moisture in soils. Their relative value in measurement of the "unfree" moisture is discussed. The principles of the methods are discussed and data are presented showing the percent of water which fails to freeze in various soils at a given temperature.

BOUYOUCOS, G. J., "Classification and Measurement of the Different Forms of Water in Soil by Means of the Dilatometer Method", Michigan Agricultural College, Experiment Station, Technical Bulletin No. 36, September 1917, 48 pp.

The author discusses the principle of the dilatometer method and its use in determining the relative amounts of free capillary adsorbed, and combined water; describes the apparatus (dilatometer) and procedure used; and presents experimental data giving the

percent unfreezable water at various temperatures for different soils. He also presents data showing volume-change, temperature relationships; the effect of salts on the amount of freezable water; and the relationship between texture and unfreezable water.

BOUYOUCOS, G. J., "Degree of Temperature to Which Soils Can Be Cooled Without Freezing", *Journal of Agricultural Research*, Vol. 20, No. 4, pp. 267-269, 15 November 1920

The results of experimental studies to determine the limit of supercooling which soils can resist without freezing.

BOUYOUCOS, G. J., "A New Classification of Soil Moisture", *Soil Science*, Vol. 11, No. 1, pp. 33-47, January 1921

The author, on the basis of past researches (listed in this bibliography), classified soil water into groups on the basis of its freezing point.

BOUYOUCOS, G. J. and MCCOOL, M. M., "A Study of the Causes of Frost Occurrence in Muck Soils", *Soil Science*, Vol. 14, No. 5, pp. 383-389, November 1922

The authors present air and soil temperature data and discuss the effect of soil color; differences in temperature of air at various elevations above ground; differences in specific heat by volume of soil; and differences in heat conductivity of soils on the occurrence of frost in muck soils.

BOUYOUCOS, G. J., "Movement of Soils Moisture from Small Capillaries to the Large Capillaries of the Soil Upon Freezing", *Journal of Agricultural Research*, Vol. 24, No. 5, pp. 427-431, 5 May 1923

The author presents data showing the effect of alternate freezing, thawing, stirring and standing on the freezing-point depression of soils. From the data, he arrives at a hypothesis on the movement of moisture from the small to the large capillaries.

BOUYOUCOS, G. J. and MCCOOL, M. M., "The Correct Explanation for the Heaving of Soils, Plants and Pavements", *Journal of the American Society of Agronomy*, Vol. 20, No. 5, pp. 480-491, May 1928

Three different types of heaving are described and an explanation of the causes of frost heaving is given. The formation of ice crystals and the movement of soil moisture associated with crystal formation are discussed.

BOUYOUCOS, G. J., "A New Electrical Resistance Thermometer for Soils", *Soil Science*, Vol. 63, No. 4, pp. 291-298, April 1947; *Highway Research Abstracts*, No. 141, p. 4, May 1947

Description of 2 new types of liquid electrical-resistance thermometers for measuring soil temperature under field conditions.

BOUYOUCOS, G. J. and MICK, A. H., "Improvements in the Plaster of Paris Absorption Block Electrical Resistance Method for Measuring Soil Moisture Under Field Conditions", *Soil Science*, Vol. 63, No. 6, pp. 455-465, June 1947.

Highway Research Abstracts, Vol. 17, No. 8, p. 5, September 1947

Description and fundamental principles of the plaster of paris block, its limitations and its advantages in determining soil moisture and the freezing point of soils.

BRYAN, KIRK, "Cryopedology, The Study of Frozen Ground and Intensive Frost-Action With Suggestions on Nomenclature", American Journal of Science, Vol. 244, 1946, pp. 622-642

Cryopedology is suggested as a suitable name for the subsience concerned with the study, both theoretical and practical, of intensive frost-action and permanently frozen ground. Sixteen other terms are also introduced and defined. Of these the important ones are pergelisol, permanently frozen ground, and molisol, the overlying seasonally thawed ground in which intensive frost-action occurs. It is believed that these and the other suggested terms will facilitate discussion of the problems of the Arctic and of the ancient frost-action of periglacial areas.

BRYAN, KIRK, "The Study of Permanently Frozen Ground and Intensive Frost-Action", The Military Engineer, Vol. XL, No. 273, pp. 304-308

Cryopedology is suggested as a suitable name for the subsience concerned with the study, both theoretical and practical, of intensive frost-action and permanently frozen ground. Sixteen other terms are also introduced and defined. Of these the important ones are pergelisol, permanently frozen ground, and molisol, the overlying seasonally thawed ground in which intensive frost-action occurs. Comments on the suitability of Professor Bryan's terminology follow the main article.

BUCKLEY, E. R., "Ice Ramparts", Transactions, Wisconsin Academy of Sciences, Arts and Letters, Vol. 13, Pt. 1, pp. 141-157, 1900

Diurnal and weekly temperature changes cause expansion of ice and shoving up of ridges of sand, gravel and boulders along shores of Wisconsin lakes. The phenomena are described and causes given but no attempt is made to prescribe criteria or methods to prevent or alleviate damage from ice thrusts.

BUETOW, W. C., "Causes and Control of Damaging Frost Action in Shoulders and Subgrades", Proceedings, 5th Annual Asphalt Paving Conference, The Asphalt Association and Association of Asphalt Paving Technologists, pp. 146-151, 1929

General description of the action of frost boils and methods used in their eradication.

BURICE, M. F., "Soil Temperature in the Matanuska Valley of Alaska", Transactions, American Geophysical Union, Part 1, 1943, p. 151

Relates to temperature above freezing and for depths of 0-2-4-8 inches.

BURTON, V. R. and BENKELMAN, A. C., "Frost Action in Silt Soils Defined by Field and Cold Room Studies", Engineering News-Record, Vol. 106, No. 7, pp. 266-270, 12 February 1931

This article is an abridgement of the author's paper of "The Relation of Certain Frost Phenomena to the Subgrade", Proceedings, Highway Research Board, Vol. 10, pp. 259-275, 1930

BURTON, V. R., "Application of Soil Science to Highway Engineering", Proceedings, 17th Annual Conference on Highway Engineering, University of Michigan, Official Publication, Vol. 32, No. 70, pp. 77-85, 20 May 1931

This article is similar to "Application of Soil Science to Highway Engineering", by V. R. Burton, Roads and Streets, Vol. 71, No. 5, pp. 163-165, May 1931.

BURTON, VICTOR R., "Application of Soil Science to Highway Engineering", Roads and Streets, Vol. 71, No. 5, pp. 163-165, May 1931

General discussion of correction and prevention of heaves and treatment of boils. Includes illustrations showing location of frost action area with respect to soil profile.

CALCIUM CHLORIDE ASSOCIATION NEWS, "Calcium Chloride Treated Roads Guard Against Spring Breakup", Calcium Chloride Assoc. News, Vol. 10, No. 3, pp. 305, June 1944

Summary of experiences in six counties in Minnesota on the effectiveness of calcium chloride introduced in holes in the subgrade in preventing spring breakup.

CALCIUM CHLORIDE ASSOCIATION, "Preventing Detrimental Frost Heaving", (by Treatment of Eruption Areas with Calcium Chloride), Information Sheet, Brief No. F-61, Revised February 1945

This pamphlet discusses correction and prevention methods, early subsoil treatments,  $\text{CaCl}_2$  admix in bases,  $\text{CaCl}_2$  maintained surfaces. Includes several photos.

CALLENDAR, H. L., "Preliminary Results of Observations of Soil Temperatures with Electrical Resistance Thermometers Made at the McDonald Physics Building, McGill University, Montreal", Transactions, Royal Society of Canada, Second Ser., Vol. 1, Sec. 3, pp. 63-84, May 1895

Description of electrical resistance thermometers and procedure used in observing temperatures of soil to depth of 9 ft. Results presented graphically show isothermal diagram for winter months, diurnal variations in air and in soil temperatures at various depths, variation of temperature with depth on various dates, and integrated curves of sunshine. Presented also is a method of computing thermal diffusivity from graphical temperature data.

CALLENDAR, H. L. and MCCLEOD, C. H., "Observations of Soil Temperatures with Electrical Resistance Thermometers", Proceedings and Transactions, Royal Society of Canada, Second Ser., Vol. 2, Sec. 3, pp. 109-126, May 1896

A continuation of the May 1895 (1895-1) report by the senior author giving more complete data on soil temperatures. The data are presented in the form of an isothermal diagram, March 1895 to April 1896, and curves showing variation in temperature with depth. A table of thermal diffusivity values are given for various seasons of

the year for various depths.

CASAGRANDE, A., "Discussion on Frost Heaving", Highway Research Board, Proceedings, 11th Annual Meeting, Vol. 11, Part 1, 1931

A discussion on the main points of differences between the Benkelman-Obmstead and Taber theories of the mechanics of frost heaving.

CASAGRANDE, L., "Effects of Frost in Soil", Permanent International Association of Road Congresses, First and Second Sec. Combined, 35th Congress, the Hague, 6th Question, pp. 10-11, 1938

Brief summary concerning the limiting grain size between frost-susceptible and non-frost-susceptible soils.

CASAGRANDE, L., "Experimental Road Sections; The Drainage of Foundations", Strasse 1938, 5(16), 529; Road Abstracts, Vol. 6, No. 1, Abst. No. 20, p. 5, January 1939. Also see Road Abstracts, Vol. 6, No. 5, Abst. No. 273, pp. 73-74, August 1938.

A discussion of the effectiveness of drainage on frost action on experimental road sections in Baden, Germany.

CASAGRANDE, L., "What Has the Frost Damage of Last Winter Taught Us", Strasse, Vol. 7, Nos. 9-10, pp. 193-201, 1940; Road Abstracts, Vol. 8, No. 11, Abst. No. 343, p. 133, 14 October 1941; Highway Research Abstracts, No. 86, pp. 7-8, January 1942

Description of the effects of exceptional hard winter of 1939-40 on German highways. A review of criteria on effectiveness of frost prevention for average winters, effect of grain size, granular bases, drainage, necessity for dowelling concrete pavements and others.

CLARK, A. C., "The Alaska Highway -- Effect of Climate and Soils on Design", Civil Engineering, Vol. 13, No. 5, May 1943, pp. 209-212; Western Construction News, Vol. 18, March 1943, pp. 105-109

This paper explains the unusual soil and climatic conditions encountered during construction of the pioneer road for the Alaska Highway and their effect on design. Discusses the difficulties encountered in construction on permanently frozen ground or ice close to the surface immediately under a heavy insulating layer of moss or grasses; on layers of ice and frozen soil occurring at depths of 3 ft or more; and where an icing condition known as "glaciating" exists. Photos.

CLARK, K. A., "Some Examples of Frost Boils Occurring on Alberta Highways", Canadian Engineer, Vol. 69, No. 11, pp. 7-10, 10 September 1935

A discussion of the physics of frost heaving, the conditions under which heaving does not occur, the relation of soil classification type to heaving; and a description of frost boil occurrences with illustrations of soil profiles in which frost boils occur.

CLAY SEWER PIPE ASSOCIATION, INC., "Clay Pipe Engineering Manual",

pp. 129-130, 1944, The Association, Columbus, Ohio

The use of subsurface drains to prevent damaging frost heave.

CONRAD, V., "Polygon Nets and Their Physical Development", *American Journal of Science*, Vol. 344, No. 4, pp. 277-295, April 1946

This paper is a summary of studies made by the author in 1933 of a well-developed stone polygon net located in the Hochschwab Mountain group of the East Alps. The small stone polygons, less than 2 meters in diameter, described in this paper, are not related to "soil polygons" in appearance or physical development. There are 3 different hypotheses explaining rock polygons. The theory forwarded by S. Högström emphasizes the pushing force of water. In the initial stage of development, the nucleus of an individual stone polygon is a bare spot in a generally rock fragment-littered surface. The fine-grained soil (clay) in the bare spot expands on freezing, resulting in differential sorting of materials according to size, the larger particles being sorted towards the perimeter of the bare spot. With recurrent freezings the size of the bare spot increases. The 2nd hypothesis by Nordenskiöld, Low and Grigg considers convectional currents in an unstable soil caused by temperature differences. The author believed this hypothesis is not applicable to development of the polygon net he examined, since the formula implies that the basic condition for instability requires a mixing ratio of 60 percent water and 40 percent fine silt. The clayey soils at the location of the polygon net described contained an average moisture content of 35 percent by weight. The last hypothesis by Stöckh stresses the fact that those soils likely to develop structures have colloidal properties. Colloidal substances (between 100 and 1 millimicrons in diameter) swell when mixed with water. The author considers colloidal swelling forces strictly a secondary factor. He is of the opinion that freezing forces are much more important. A detailed statistical analysis of field measurements of 37 polygons is given. An estimated frequency maximum for polygon interior angles occurs at 120°. This indicates a distinct tendency towards the formation of equilateral hexagons exists. Of the 37 polygons measured, 86 percent of the legs were between 31 to 110 cm long. A bibliography of 28 references is listed.

CRESSY, G. B., "Frozen Ground in Siberia", *Journal of Geology*, Vol. 47, No. 5, pp. 472-483, July-August 1939

A discussion of the types, depths, distribution of, and research history on permanently frozen ground in Siberia. Included also is a discussion on Pleistocene glaciation and present climatic conditions in Siberia and causes of permanently frozen ground (permafrost).

DACHNOWSKI-STOKES, A. P., "Peat Resources in Alaska", U. S. Dept. of Agriculture, Technical Bulletin TB 769, April 1941, pp. 64-65

This bulletin is based upon field work in 1939. It gives a general

classification of most of the peat areas in Alaska. Among the conclusions stated is the following: "Among the qualifying factors that affect muskegs in the interior of Alaska are layers of volcanic ash, windblown silt, and a permanently frozen condition. The line of permafrost appears to have been rising periodically. Summer thawing ranges usually between 20 to 45 inches below the surface." It is estimated that about 50 million acres of Alaska may be classified as forest, approximately 100 million in tundra and nearly 110 million in muskeg and grassy marshland. The term "muskeg" is of "Indian (Algonquin) origin denoting an area covered with sphagnum mosses and tussocks of sedges".

D'APPOLONIA, ELIO, "Foundations in Permafrost Regions", Northwest Service Command Report, 1 August 1944, Tentative Report

Part I deals with construction in permafrost regions and shows the results of improper construction in various buildings at the Koidern Repeater Station, Y. T., and Northway, Alaska. Points out in each case that construction was done incorrectly because of lack of knowledge that the transfer of heat caused melting of permafrost and settlement to failure of many of the structures; that construction with an air space using piling is a solution of the problem.

D'APPOLONIA, E., "Permanently Frozen Ground and Foundation Design, Part 2", Engineering Journal (Canada), Vol. 29, No. 1, pp. 7-12, January 1946

Reasons for failure of foundations for structures on permafrost and examples of designs to prevent melting of permafrost and causing excessive settlement of foundations.

DARTON, N. H., "Geothermal Data of the United States", U. S. Geological Survey Bulletin No. 701

Temperature given for wells, mines, etc.

DEMENTIEV, A. I. and TUMEL, V. F., "Civil Engineering in Frozen Soil, USSR", Canadian Geographical Journal, Vol. 32, No. 1, pp. 32-33, January 1946

A brief general description stating that progress has been made in combating drifting snow, mining, construction on permafrost: (one statement that buildings are designed to prevent thawing, another that subsoil is warmed electrically using 300 to 1300 volts); and in the problem of drinking water in the eternally frozen areas (artesian wells through 700 ft of permafrost to depth of 1600 ft at Irkutsk). Permafrost covers 47 percent of area of USSR.

DENNY, C. S., "Stone-Rings on New Hampshire Mountains", American Journal of Science, Vol. 238, No. 6, pp. 432-438, June 1940

Description of miniature stone rings and stripes of modern date. No attempt is made to describe their mode of formation. Bibliography.

DEPARTMENT OF THE ARMY, "Pile Pullout Tests in Frozen Ground",  
Headquarters, Air Materiel Command, Air Installations Division, February  
1948

In this memorandum, Mr. L. A. Nees deals with experiments by the author made at the Wright-Patterson Air Force Base. One- and 1/4-in. black steel pipe, 6-, 12-, 18- and 24-in. lengths, were used as test piles and frozen into one cubic yard of soil. The pull-out resistance did not go below 40 lb per sq in. except where the soil was very dry. The pull-out resistance increased rapidly as the optimum moisture and density were approached. Although the tests are admittedly lacking in adequacy, it was concluded of the work that a working value of 20 lb per sq in. could be safely adopted as the pull-out resistance value and that the tests should be supplemented by prototype tests as well as more laboratory work. It is also noted that the minimum permissible length of pipe below permafrost table should be 20 ft, and the minimum depth of a pile joint below permafrost table should be five ft. These tests were made for use in designing the Loran tower at Project Beetle Able (Skull Cliff).

DEPARTMENT OF THE ARMY, "Data on Frost Action", District Soils  
Laboratory, U. S. Engineer Office, Providence, R. I.

This manuscript, which was compiled in the District Soils Laboratory, is a brief abstract of various articles given in the references at the end of the article. It covers frost action in subgrades and surfaces based on information obtained from Iowa, Sweden, Minnesota, South Carolina, New Hampshire, Maine, Indiana, Washington, Massachusetts, Connecticut, New York, Michigan, Germany, and Canada. In general, it discusses the matter of moisture content, specific heat, densities, color, and degree-days, and capillarity insofar as they affect frost heaving.

DOCKSTADER, E. A., "Effect of Freezing and Thawing of Soil Under Foundations of Cold Storage Warehouse", Proceedings, International Conference on Soil Mechanics and Foundation Engineering, Harvard University, Vol. 2, pp. 171-173, June 1936

Factual data on depth of frost, height of heave due to heaving of foundation soil and settlement of foundation of a nine story cold storage building under controlled thawing.

DUCKER, A., "Ueber 'Bodenkolloide' und ihr Verhalten bei Frost" (Soil Colloids and Their Behavior when Subjected to Frost Action), Der Bauingenieur, Vol. 23, pp. 235-7, 5 August 1942. (Translated by H. B. Edwards, Engineer Department, Research Center, U. S. Waterways Experiment Station, Vicksburg, Miss., December 1944).

Review of and discussion on the Schmid and the Casagrande criteria for the effect of frost on a soil; data and discussion on results of freezing tests on soil colloids; bibliography.

DUCKER, A., "Untersuchungen über die Frostgefährlichen Eigenschaften Nichtbindiger Boden", (Investigations on the Frost Danger Element of

Cohesionless Soils), Forschungsarbeiten aus dem Strassenwesen, Band 17, 1939, 79 pp. (In German).

The results of experimental studies on the effect of texture of noncohesive soils and the freezing of texture fractions of soils and their mixtures.

EARDLEY, A. J., "Unconsolidated Sediments and Topographic Features of the Lower Yukon Valley", Bulletin of the Geologic Society of America, Vol. 49, pp. 303-342, February 1938

Report contains important material -- geologic and topographic -- on lower Yukon. Report locates gravel, sand, silts, and muck; their origin is a problem, but some conclusions are stated. In general, it appears in the most part to be fluvial, but the silt a combination of fluvial and aeolian. Mentions ice lenses and frozen ground. Many good photographs illustrate features discussed in text and show general topography of region; many oblique air photographs. Tables are used in silt identification, soil sizes and comparisons. Sketches demonstrate text and include valley cross sections, general topography around stream, extent of glaciation in area. Bibliography includes many U.S.G.S. references on Alaska.

EKBLAW, W. E., "The Importance of Nivation as an Erosive Factor and of Soil Flow as a Transporting Agency in Northern Greenland", Proceedings, National Academy of Sciences, Vol. 4, No. 9, pp. 288-293, 15 September 1918

A description of the process of nivation (the formation and melting of snow-ice) and its effect on the disintegration of rocks; the destruction of some land forms and the formation of others. A description of solifluction (soil flow) and its connection with nivation is also given.

ELGAR, W. H., "Soil Movements as Affecting Paved Surfaces; Mechanics of Frost Heaving", Surveyor, (London), Vol. 103, No. 2746, pp. 427-8, 8 September 1944. Abstract of article in Public Works, Vol. 75, December 1944, pp. 17-18

Discussion of changes in water content and frost action and the manner in which resulting movements affect rigid and flexible surfaces.

ELIAS, M. M. and VOSBURGH, R. M., "Permafrost Program -- Progress Report No. 1 -- Terrain and Permafrost in Galena Area", U. S. Geological Survey, 1946

This report is a study of terrain and permafrost in a part of one of the large alluvial basins which characterize the topography of central Alaska. The report describes the general terrain of the basin, the relationship of ground and permafrost conditions to topography, suitability of the terrain units for construction, and criteria for interpreting the terrain from aerial photographs. The report presents the results of field investigation of two terraces near the Galena Air Base; the suitability of the two terraces for possible airfield sites is discussed.

EMREY, D. J. "Subgrade Soils, Their Analysis and Drainage", Canadian Engineer, Vol. 72, No. 12, pp. 5-9, 23 March 1937; also Vol. 72, No. 13, 30 March; and No. 15, 13 April 1937.

A review of published material (largely from Public Roads Administration, New Hampshire and Michigan sources) on subgrade soils, classification, frost heaving and drainage. Included is a good popularly written review of the theory of frost heaving and a number of figures illustrating installation of underdrains to intercept seepage.

ENGINEERING AND CONTRACT RECORD, "Extent of Frost Penetration in Soils", Vol. 50, No. 89, p. 11, 8 September 1937

A tabulation of depth of frost penetration at ten locations and depth of permafrost at five locations in Canada.

ENGINEERING AND CONTRACT RECORD, "Inexpensive Treatment for Frost Boils Helps Prevent Costly Pavement Repairs", Engineering and Contract Record, Vol. 55, No. 42, p. 33, 21 October 1942

Brief discussion on drainage, crack sealing and use of calcium and sodium chloride to prevent frost heave.

ENGINEERING NEWS-RECORD, "Frost Penetration Studies at Portland, Maine", Engineering News-Record, Vol. 116, No. 15, p. 537, 9 April 1936

Discusses studies of frost conditions at Portland, Maine being carried out by the city water department. Thermometers are set in the ground at 6-in. intervals to a depth of 5-1/2 ft.

ENGINEERING NEWS-RECORD, "Impervious Bituminous Wall Suggested to Prevent Seepage Under Paving", Engineering News-Record, Vol. 81, No. 5, pp. 226-228, 1 August 1918

A staff review of J. W. Lowell's "An Investigation of the Vertical Movements of Concrete Pavements", Proceedings, American Concrete Institute, Vol. 14, pp. 366-373, 27-29 June, 1918.

ENGINEERING NEWS-RECORD, "Highway Progress and Investigations", Engineering News-Record, Vol. 105, No. 25, pp. 978-981, 18 December 1930

A staff review of the "Relation of Certain Frost Phenomena to the Subgrade", by V. R. Burton and A. C. Benkelman, Proceedings, Highway Research Board, Vol. 10, pp. 259-275, 1930

ENGINEERING NEWS-RECORD, "Ice Pressure Determinations in Clay Soils", Engineering News-Record, Vol. 115, No. 4, p. 127, 25 July 1935

Staff review of a paper given by A. Casagrande at the 1935 meeting of the Society for the Promotion of Engineering Education. The review gives data and shows graphically the unit pressures (in a consolidation test) required to reduce the soil moisture contents to the values obtained during ice segregation in freezing tests.

ENGINEERING NEWS-RECORD, "Mitigating Frost Action on Road

Surfaces", Vol. 104, pp. 1021-23, 19 June 1930

A staff review of and extracts from the report of the Committee on Subgrades and Pavement Bases, 1930 convention of the American Road Builders Association. Discussed are: surface damage from freezing and thawing; granular subbases; and drains and backfilled trenches.

ERLENBACH, L., "Recent Observations and Research on Frost Damage in East Prussia", Strasse 1937, 5(2), 42-6; Road Abstracts, Vol. 5, No. 3, Abstract No. 139, pp. 39-40, May 1938

A description of severe longitudinal cracking and heaving in East Prussia during the severe winter of 1936-37; nature of the soil, nature of the sand used in the "protective course"; and ineffectiveness of drainage by side ditches to prevent frost damage.

FEUSTEL, I. C., DUTILLY, A. and ANDERSON, M. S., "Properties of Soils from North American Arctic Regions", Soil Science, Vol. 48, No. 3, September 1939, pp. 183-200

This paper includes the chemical and mechanical analyses, mineralogical composition and organic content determinations of soil samples collected at 15 widely scattered locations from Churchill north to the 76th parallel. A detailed description of 37 samples is given, including the geological classification of parent rocks, vegetation types, groundwater conditions, and soil acidity. The influences of mechanical weathering forces, especially freezing, thawing and wind action predominate in arctic regions. The soils are characterized by the presence of unweathered rocks and rock fragments. Normal soil-forming processes of eluviation and illuviation are greatly retarded under the frigid climatic conditions. Tundra soil formations appear to be related to marsh types resulting from excessive moisture. Much of the area is overlaid with peat or muck. Organic residues do not readily decompose but tend to accumulate on the surface as peat or peat-like materials. Most of the samples collected were acid and none were strongly alkaline. Of the 37 samples collected, only 3 of the soils contained 20 percent clay and nearly half had less than 5 percent. A large amount of the material was greater than 0.5 mm in diameter. The carbon nitrogen ratios of mucks and peats are comparable to those occurring in Maine. Where lichens contribute to peaty accumulations, low carbon contents and low carbon-nitrogen ratios are expected. Reference is made to a shallow, clayey, alluvial soil found in a polygonic formation near Ft. Burwell, N.W.T. The authors state "the process of polygon formation is presumably directly related to a flooding or saturation of the soil with water followed by evaporation and resultant contraction of the material.....a factor of particular importance relative to shrinkage behavior of this solid would seem to be the ratio silica to total bases". Very low ratio silica to total bases (3-5) is characteristic of arctic soils. Sodium content, on the other hand, is very high

(approximately one percent). Exchangeable sodium in soil colloids tends to increase their capacity for swelling and shrinkage. The chief constituent of the soil colloids is hydrous mica, commonly called Ordovician bentonite. A bibliography of 20 references is included.

FROST, R. E., "The Use of Aerial Maps in Soil Studies and Location of Borrow Pits", Purdue University. Reprinted from Kansas Engineering Experiment Station Bulletin 51, 1 July 1946

This article deals with the use of aerial maps in soil studies as indicated in the title. It points out that one of the chief advantages of mapping soils from aerial photos lies in the fact that detailed soil maps cannot be made in any other way at a comparable cost, or made as efficiently from the standpoint of time. The basis for this is that soil and rock patterns are repetitive in their natural environment which means that any two materials derived from the same soil or rock pattern material, both having undergone the same relative topographic position, under the same climate and both occupying the same relative topographic position, will have similar soil profiles, engineering properties, native vegetation, and air-photo pattern. Other requirements are that the photographs be of good quality so that stereovision is possible. The pamphlet is well illustrated with photographs and soil maps made from the adjoining photographs.

FRY, W. H., "Petrographic Methods for Soil Laboratories", Department of Agriculture, Technical Bulletin TB No. 344, January 1933, p. 95

This bulletin discusses in detail the fundamental properties of light, the petrographic microscope, optical methods and the application of methods.

FULLER, H. U., "Frost Penetration as Affected by Weather and Snow Conditions", Journal of the New England Water Works Association, Vol. 50, No. 3, pp. 299-301, September 1936

A discussion of frost penetration, depth of snow blanket, depth of frost penetration, and temperature deficiency (freezing index) at Portland, Maine.

FULLER, H. U., "Studies of Frost Penetration", Journal of New England Water Works Association, Vol. 54, No. 3, pp. 275-281, September 1940

Data are presented showing depth of frost penetration and soil temperatures in gravel and clay. Temperature deficiency curves show the range of severity of the winters at Portland, Maine.

GARDNER, D. L. and WRIGHT, G. C., "Frost Heave Measurements for 1938-1939", A thesis in partial fulfillment for the Degree of Bachelor of Science, University of New Hampshire, 1939, 45 pp.

Report of the continuation of a study of the relation between accumulated air temperatures and frost heave begun in 1928 under the direction of Professor A. Casagrande. The thesis reports data obtained during the winter of 1938-1939.

GARDNER, R., "Some Effects of Freezing and Thawing on the Aggregation and Permeability of Dispersed Soils", *Soil Science*, Vol. 60, No. 6, pp. 437-443, December 1945

A discussion on the effect of freezing on soil aggregation and permeability with experimental data on restoration of structure to puddled saline (sodium) soils; and the effect of freezing on the permeability of dispersed soils.

GARNEAU, J. B., "Discussion of 'Soil Stabilization and Prevention of Frost Heaves'", *Canadian Engineer*, Vol. 77, No. 12, pp. 52-54, September 1939

A review of data on frost penetration, drainage, grain size, and the mechanics of frost heaving. Included is a table of depths of frost penetration in 8 principal cities of Canada.

GESLIN, H., "The Rate of Freezing in Soil and Its Dependence on the Thickness of the Snow Layer", *Comptes Rendus (France)*, 1942, 214 (3), 124-5. *Building Science Abstracts*, Vol. 16 (New Series), No. 1, January 1943. *Highway Research Abstracts*, No. 99, p. 8, April 1943

Depth of snow cover necessary to prevent freezing of the underlying soil.

GILBERT, G. K., "Lake Bonneville", U. S. Geological Survey, Monograph, No. 1, 1890, 438 pp.

A classic on the history of ancient Lake Bonneville. Discussion of ice ramparts, glaciation, glacial deposits and associated phenomena of general interest in the study of ice. Data of direct value in study of frost action in soil are not given.

GILBOY, G., "Soil Mechanics Research", *Proceedings, American Society of Civil Engineers*, Vol. 57, No. 8, pp. 1185-1186, October 1931

An explanation of the mechanics of frost action based on results of field laboratory studies in cooperation between U. S. Bureau of Public Roads, the State of New Hampshire, and M.I.T.

GILKEY, H. J., "Freezing Ground Acts Like Hydraulic Jack", *Engineering News-Record*, Vol. 79, No. 8, pp. 360-1, 23 August 1917

A brief statement concerning heaving of bridge piers to the extent of 2-1/2 in.; 36,000-lb piers founded on blue clay 3-1/2 to 4-1/4 ft below the surface. The location is given as "an important midwestern city".

GOODELL, B. C., "Soil Boring Tool for Frost Depth Determination", *Journal of Forestry*, Vol. 37, No. 6, pp. 457-9, June 1939

An illustrated description of a small-diameter boring tool (soil tube) for determining depth of frost penetration.

GOULD, O. B., "Tile Drains Solve Frost Boil Problems", *Roads and Streets*, Vol. 71, No. 7, pp. 257-258, July 1931

A description and tabulation of cost data of trenching, back-filling and installation of drain tile for correcting frost boils in Washtenaw County, Michigan on 8 roads.

GOTTSTEIN, E., "Fundamentals on Frost Damage to Roads, Its Causes, and Prevention", Berlin, 1937 (Volk and Reich Verlag), p. 19, Fig. 28; Road Abstracts, Vol. 5, No. 2, Abst. No. 74, p. 21, April 1938

An abstract of an original article dealing with the underlying principles of frost effects and measures to obviate the damage. The author gives experience on German roads during the severe winter of 1935-36 and refers to a comprehensive bibliography by H. Petermann and E. Boedeker (see Road Abstracts, 1937-38, Vol. 4, No. 213).

GRIM, R. E., "The Clay Minerals in Soils and Their Significance", Illinois Geological Survey, Circular No. 65, pp. 11-12, 1941

Relation of frost heaving to clay mineral composition; clay minerals discussed include montmorillonite, kaolinite and certain illite soils.

HARDY, R. M., "Permanently Frozen Ground and Foundation Design, Part I", Engineering Journal (Canada), Vol. 29, No. 1, pp. 4-7, January 1946

Limited largely to discussion of permafrost but includes a review of theories of frost heave, and shows relationship between soil types and ice segregation in permafrost.

HARDY, R. M., "Research on Frost Action in Soils", Roads and Bridges (Canada), Vol. 84, No. 9, pp. 74-77, 102, September 1946

General review of the work of Taber, Beskow, and Casagrande; discussion of methods for correcting frost heaves; and a description of permafrost.

HARRINGTON, E. L., "Soil Temperatures in Saskatchewan", Soil Science, Vol. XXV

Thermometers were placed in the ground at depths from 1 to 8 ft at the University of Saskatchewan at Saskatoon. It is pointed out that the temperature varies rapidly at the 1-ft level and that the lag in soil temperature below a 2-ft depth is marked. A comparison of the temperatures at Saskatchewan with those obtained by other observers in Kansas is made. It is pointed out that the maximum temperature at the 8-ft depth was reached in April and the first half of May. Permafrost is not discussed in this article. Graphs showing the results are included.

HARRISON, J. L., "First Frost is Never Responsible for Cracked Concrete Roadways", Engineering News-Record, Vol. 80, No. 9, pp. 418-420, 28 February 1918

An attempt to establish the hypothesis that heaving can occur only as a result of more than one "freeze" of the subgrade soil. No literature is cited and no supporting data are given. The author bases thickness of subbase design on the maximum depth of winter thaws.

HAWKES, L., "Frost Action in Superficial Deposits, Iceland", Geological Magazine (London), Vol. 61, No. 725, pp. 509-513, November 1924

A description of several distinct types of effects of frost action

in surface deposits in Iceland. Included are cracks in clays, knolls in grasslands, rings of stone, and formation of shallow hollows in gravels.

**HEATING AND VENTILATING, "Frost Penetration in Ground", Heating and Ventilating, Vol. 35, No. 6, pp. 53-56, June 1938**

A charted map of the U. S. showing maximum depth of frost penetration. Tabulated data are also given on maximum frost penetration in ground in 100 cities and average frost penetration in more than 200 cities in the 48 states.

**HEJE, K., "Studies of Frost Heaving Carried Out at the Norwegian Technical College and Their Economic Results", Meddelande Veidirekt Norsk Ing. Foren, 1941 (6), 65-71. Road Abstracts, Vol. 9, No. 6, Abst. No. 217, p. 67, May 1942**

Required depth of non-frost-susceptible granular bases, insulating materials and drains to prevent detrimental heaving; frost storage capacity (freezing index); and costs of various methods of preventing frost damage.

**HENTON, J. T., "Modern Subdrainage Proves Successful Cure for Frost Boils", Highway Magazine, Vol. 19, No. 12, pp. 316-318, December 1928**

A brief article describing the installation and performance of a corrugated metal pipe on state trunk highway No. 60 west of Columbus, Wisconsin to prevent frost boils.

**HEWES, L. I., "American Highway Practice", Vol. 1, pp. 183-184, 1942 John Wiley and Sons, New York**

Includes a summary statement on theory of frost heaving.

**HIERONYMUS, G., "Earth Ambient Temperatures for Cable Loading Limits", Electrical World, Vol. 122, No. 24, pp. 92-93, 9 December 1944**

Results of a study of air and ground temperatures in Kansas City, Mo. to determine relationship between temperature and depth; cyclic changes from year to year; lag between surface air and earth temperatures at various depths; and location of "sink" value at which there is no apparent response to variation of surface air temperatures.

**HIGHLAND, SCOTLAND G., "Study of Year Round Soil Temperatures", Journal, American Water Works Association, Vol. 16, No. 3, pp. 342-354, September 1926**

Includes tabulated data on year-round temperatures at Clarksburg, W. Va., and depth of frost penetration in 11 cities in U. S. and Canada.

**HILL, E. M. M., Chief Engineer, "Memo Re Perpetually Frozen Subsoil Observations in the Vicinity of the Hudson Bay Railway", Canadian National Railways, Winnipeg, Manitoba, Canada, 29 March 1940**

This article deals with perpetually frozen subsoil in the regions of the Province of Manitoba principally. It is pointed out that the southern boundary of permafrost exists somewhere

between latitude  $54^{\circ}30'$  and  $55^{\circ}00'$  in Manitoba. Permafrost in this area may exist in the form of islands. North of  $56^{\circ}30'$  latitude, permafrost and tundra vegetation are continuous. There is a table showing thickness of permafrost in various parts of Manitoba, Northwest Territory and the Yukon Territory. A list of references regarding frost and soil temperatures in Canada is given.

HOBBS, W. H., "Soil Flow", Bulletin, American Geographical Society, Vol. 45, No. 4, pp. 281-284, April 1913

Discussion and explanation of the phenomena of freezing and thawing as related to the formation of soil polygons and the lifting of rock fragments and depositing them on edge at the edge of the polygon. Some discussion given to soil flow as the result of freezing and thawing.

HOGENTOGLER, C. A., WINTERMEYER, A. M. and WILLIS, E. A., "Sub-grade Soil Constants, Their Significance, and Their Application in Practice," Public Roads, Vol. 12, Nos. 4 and 5, pp. 89-108, 116-144, June and July 1931

The authors review the work of Bouyoucos and Faber and discuss the frost-heave characteristics of the various Public Roads Administration soil groups.

HOGENTOGLER, C. A., "Engineering Properties of Soil", pp. 127-158, 1937, McGraw-Hill Book Co., New York

Heat transfer, insulating properties of materials, effect of air temperature, effect of types of covering, growth on freezing, direction of growth, ice lenses responsible for heave, freezing of supercooled water, heave in permeable soils, heave in soils of high capillarity, moisture requirements for frost heave, effect of soil character, results of controlled experiments, effect of climatic changes, effect of soil profile, effect on road surfaces, and drainage of frost-heaving silts.

HOGENTOGLER, C. A., and BARBER, E. S., "The Trend of Soil Testing", Proceedings, 18th Annual Meeting, Highway Research Board, Part II, December 1938, pp. 9-34

The article is a resume of soil test methods and the significance of test data. Subjects discussed include the following: dominant colloidal phenomena; apparent volume of soil fractions; effect of film moisture on the stability of the soil; effect of electrolytes; internal forces retain high density of soil; stability of soil determined by test; the consolidation test and its applications; shear tests; compaction tests; and indicator tests.

HUGHES, A. C., "Frost Damage to Roads on a Chalk Subsoil", Surveyor (London), Vol. 106, No. 2909, pp. 581-582, 7 November 1947

A general descriptive article on depth of frost penetration and effect of drainage, exposure, subsurface water through cracks in pavements, grades, cuts, embankments, and traffic on frost

heaving and frost boils; and the nature of successful treatments.

HUNTING, M. T., "Geology in Highway Engineering", Transactions, American Society of Civil Engineers, Vol. 110, pp. 278-280, 1945

A brief and general review of the area affected by frost action, Taber's work, and the cooperative survey between the state highway departments of Michigan, Minnesota, Wisconsin and the Public Roads Administration.

HVORSLEV, DR. M. JUUL, "The Present Status of the Art of Obtaining Undisturbed Samples of Soils", March 1940, Harvard University

This report is divided into two main parts. In the first part is given an analytical review of the character and influence of the various types of disturbance to the soil sample and of the problems encountered in securing such samples with a minimum of disturbance. The second part contains a comprehensive review of the methods and equipment currently used to obtain undisturbed samples of soils in this country and abroad. Bibliography.

INGERSOLL, L. R. and KOEFF, O. A., "Thermal Diffusivity and Conductivity of Some Soil Materials", Physical Review, Vol. 24, No. 1, pp. 92-93, July 1924

The authors present a method of measuring diffusivity and give tabulated data on percentage moisture, diffusivity, specific heat, density and conductivity for four different soil materials and densely packed snow.

IVIE, J. O. and RICHARDS, L. A., "A Meter for Recording Slow Liquid Flow", Review of Scientific Instruments, Vol. 8, No. 3, New Ser., pp. 86-89, March 1937

A description is given of a reversible flow meter designed to work as a part of a soil moisture flow gauge. The flow of water through the soil is recorded by forming drops of water in a less dense nonmiscible liquid and recording the drops electrically. The operating characteristics are discussed and an empirical equation derived giving the effect of temperature and flow rate on size of drop.

JAILLITE, W. MARKS, "Permafrost Research Area", The Military Engineer, September 1947, Vol. XXXIX, No. 263, pp. 375-379

This article describes construction by the Corps of Engineers, Dept. of Army, of a research area near Fairbanks, Alaska for the purpose of studying the effect of permafrost (permanently frozen ground) on various types of foundations, using different kinds of insulation, piling, gravel fills, etc. Some of the difficulties of construction are described, including what happens when flowing artesian well is obtained when drilling for water through the frozen ground.

JOHNSON, A. W., "Frost Action in Subgrades and Bases", Roads and Bridges, (Canada), Vol. 85, No. 9, pp. 104-110, 146-150, September 1947:

also Engineering and Contract Record, Vol. 60, No. 11, pp. 64-83, November 1947

A review of literature on factors which determine the nature of frost action, freezing and heaving of saturated soils; depth to water table, its effect on heaving; effect of dissolved substances; freezing of nonsaturated soils; effect of nature of materials; and design to reduce or prevent the detrimental effects of frost action.

JOHNSTON, W. A., "Frozen Ground in the Glaciated Parts of Northern Canada", Transactions, Royal Society of Canada, Third Ser., Vol. 24, Ser. 3, pp. 31-40, 1930

A review of work by other investigators on permafrost.

JURGENSEN, L., "Field Test for Identification of Soil Capable of Frost Heaving", (English Summary), Proceedings, International Conference on Soil Mechanics and Foundation Engineering, Harvard University, Vol. 2, Appendix, 22-26 June 1936

A rapid field test to identify frost-susceptible soils; the test is based on rate of settlement when suspended in water, the quantity of fines being related to the depth of sediment.

KEEN, B. A. and RUSSELL, E. J., "The Factors Determining Soil Temperature", Journal of Agricultural Science, Vol. 11, Pt. 3, pp. 211-239, July 1921

This article presents soil and air temperature data, describes apparatus and methods of obtaining soil temperatures, and discusses factors which influence soil temperatures, bringing out the relationship between soil and air amplitudes.

KEEN, B. A., "Soil Temperature", The Physical Properties of Soil, Chapt. 9, pp. 295-333, London, Longmans, Green and Co., 1931

A discussion of the effect of temperature of earth's interior, solar radiation, latitude and slope of ground, altitude, distribution of land and water, vegetative cover, winds, snow, frost, and nature of soil on soil temperature; and of the characteristics of temperature waves in soil.

KEIL, K., "How Can We Judge the Liability of Stratified Rocks to Frost Damage", Strassenbau, 1937, 28(9), pp. 107-115. Road Abstracts, Vol. 4, No. 8, Abst. No. 348, pp. 121-122, Nov. 1937

A general discussion of various rocks and their susceptibility to frost action.

KEIL, K., "Results of a Frost Action Study in a Stretch of Motor Road", Strassenbau, 1938, 29 (5), pp. 67-71; (6) pp. 94-97; (7) pp. 124-129. Road Abstracts, Vol. 5, No. 5, Abst. No. 275, pp. 72-74, August 1938

Experiments involving use of "protective" courses of sandy gravel and fresh quarry waste; dowels in concrete pavements; waterproof fabrics to limit moisture movement in the subgrade; and underdrains are described. Conclusions are given on the possibility of arriving, in advance of construction, at a

mathematical determination of expected danger from frost which will enable suitable preventive measures to be taken; the effectiveness of dowelling concrete pavements; and the required minimum thickness of granular bases to prevent damage due to frost.

KERSTEN, M. S., "Survey of Subgrade Moisture Conditions", Proceedings, Highway Research Board, Vol. 24, pp. 497-512, 1944

Compilation and analyses of data on soil moisture under existing highway pavements.

KERSTEN, M. S., "Subgrade Moisture Conditions Beneath Airport Pavements", Proceedings, Highway Research Board, Vol. 26, pp. 450-463, 1945

An analysis of subgrade moisture data from subgrades under flexible and rigid type airfield pavements in 17 states.

KIMBALL, D. A., UHNKE, G. N., and GLOVER, M. P., "A Comparison of Temperatures in Air and at Various Depths in a Light Sandy Soil in Southern Ontario", Scientific Agriculture (Canada), Vol. 14, No. 7, pp. 353-359, March 1934

An example is given of recorded temperature data taken with recording thermograph of the 2-pen type with mercury in steel cables. Tabulated data are given showing average monthly temperatures of air and of the soil at depths of 4, 12 and 24 in. from July 1930 to June 1932.

KINCER, J. B., "Precipitation and Humidity", Atlas of American Agriculture, Pt. 2(Climate), Sec. A(Precipitation and Humidity), Advance Sheets, No. 5, 15 March 1922.

Charted maps of the U. S. giving data on precipitation and humidity on basis of monthly, seasonal and annual averages. Records for the uniform 20-year period, 1895-1914, were used in constructing the principal charts and diagrams.

KINCER, J. B., "Temperature, Sunshine and Wind", Atlas of American Agriculture, Pt. 2(Climate), Sec. B.(Sunshine and Wind), Advance Sheets, No. 7, November 1928

Charted maps of the U.S. and diagrams giving data on temperature, sunshine and wind, on basis of monthly, seasonal and annual values. Records cover the uniform 20-year period, 1895-1914.

KRYNINE, D. P., "Soil Investigations in Russia", Proceedings, Highway Research Board, Vol. 9, pp. 66-74, 1930

Author presents general review of soil studies in USSR. General history, soil profiles, design of soil mixtures, frozen soils, rolling of earth roads, and research are briefly discussed. As to frozen soils, author notes difference as to freezing and thawing when area is insulated, also the destructive effect and inherent instability of roads on these areas. Bibliography of 8 titles (mostly English) are noted.

KRYNINE, D. P., "Soil Mechanics, Its Principles and Structural Applications", 1st Ed., pp. 77-84, 1941, McGraw-Hill Book Co., New York

General discussion of frost action, freezing point, ice crystals, open and closed systems, influence of the size of particles, massive and ice stratified frozen formations, mechanics of moisture movement during the soil freezing process, capillary capacity and permeability as controlling the maximum amount of heave, and technical measures against frost action.

KRYNINE, D. P., "Some Experiments on Capillary Flow of Moisture Through Gravels and Silts", Proceedings, Twenty-sixth Annual Meeting, Highway Research Board, 1946, pp. 474-483

Capillary movement of moisture in gravels and silts, and also in combined systems (silt-sand and silt-screenings) is described in this paper. The experiments were performed in large lucite tubes, 5-5/8 in. and 3-1/8 in. in diameter and 4 ft high. The shape of the time curves obtained by plotting the height of the visible moisture boundary against time was parabolic of variable order.

LANCASTER, C. M., "Discussion on Survey of Subgrade Moisture Conditions", Proceedings, Highway Research Board, Vol. 24, pp. 512-513, 1944

Significant data from a long-time moisture study under flexible-type pavements in Missouri.

LANE, A. C., "Northern Climatic Variations Affecting Geotherm Initial", Canadian Mining and Metallurgical Bulletin, No. 411, pp. 397-402, July 1946

A review of the works of Fitton and Brooks (Monthly Weather Review, Vol. 59, pp. 6-16, January 1931), on the relationship between air and soil temperatures in the upper few inches of permanently frozen ground with remarks by the author.

LANG, F. C., "Frost Action in Highway Subgrades and Bases", Discussion, Proceedings, Purdue Conference on Soil Mechanics and Its Applications, Purdue University, Symposium on Frost Action, pp. 457-460, 2-6 September 1940

Description of heaving in the form of high joints in portland cement concrete pavements in Minnesota and means of preventing their occurrence. Data on change in density of a clay soil subjected to absorption and freezing and thawing are included.

LANG, F. C., "Discussion -- Subgrade and Pavement Bases", Proceedings, 27th Annual Convention, American Road Builders Association, pp. 508-516, 1930

A description of frost heaving and frost boils and a suggested means of "curing" frost boils.

LANG, F. C., "Soil Science Applied to Flexible Surfaces", Better Roads, Vol. 5, No. 2, pp. 20-27, February 1935

A general descriptive article illustrating (1) position of frost boil in structureless silt in soil profile; (2) excavation

of frost-susceptible soils; (3) frost heaving with respect to position of ledge rock; (4) grading of materials and typical cross section of gravel bases used and their relation to road surface condition; (5) underdrain practice; and (6) adjustment of grade line to avoid frost-susceptible soils.

LANG, F. C., "Combating Frost and Drainage Problems", Proceedings, 23rd Annual Road School, Purdue University, Engineering Bulletin, Vol. 21, No. 3 (Extension Ser. No. 39), pp. 46-56, May 1937

This article is similar in content to "Soil Science Applied to Flexible Surfaces", by F. C. Lang, Better Roads, Vol. 5, No. 2, pp. 20-27, February 1935

LANG, F. C., "Progress Report of Committee on Freeze-Proofing Treatment of Subgrade Soils with Calcium Chloride to Prevent Detrimental Frost Action", Special Committee of the Highway Research Board, 1944, Highway Research Abstracts, No. 118, pp. 9-10, March 1945

A description of installations in Michigan, Minnesota, and Indiana in which calcium chloride was introduced into the subgrade through holes in the pavement to prevent frost heave.

LAUHLI, E., "Ground Temperature Variations Decrease with Depth", Engineering News, Vol. 74, No. 11, pp. 510-511, 9 September 1915

A brief statement on the need for steel in a cutoff wall to care for local stresses set up by temperature changes at different depths. Included are five time-temperature charts showing mean air and ground temperatures.

LEFFINGWELL, E. DeK., "Ground-Ice Wedges; The Dominant Form of Ground-Ice on the North Coast of Alaska", Journal of Geology, Vol. 23, No. 7, pp. 635-654, October-November 1915

A description of soil polygons and inclosing wedges of ground ice with an explanation of their origin and growth.

LEWIS, M. R., "Rate of Flow of Capillary Moisture", U. S. Dept. of Agriculture, Technical Bulletin No. 579, October 1937, 29 pp.

The results of experimental studies in which water was added at various predetermined rates to one end of a number of soil columns which were exposed at the other end to a current of air maintained at a constant temperature and humidity. The purpose of the experiment was to determine the distance through which water can be moved by capillary forces in a range of moisture between the field capacity and the permanent wilting percentage. Data and discussion are included on effect of soil type and gravity on rate of flow, and moisture content gradient for different rates of flow. Bibliography.

LINDE, S. F., "The Freezing of the Foundation Soil Under Cold Storage Buildings", Warme u. Kältetechnik, 1942, 44(2), 17-23; (3) 34-8; Building Science Abstracts, Vol. 16 (New Ser.), No. 3, Abst. No. 198, p. 41, March 1943

Soil temperatures correlated with vertical movements of a cold

storage warehouse and conclusions concerning design of foundations for cold storage warehouses.

LOWELL, J. W., "An Investigation of the Vertical Movements of Concrete Pavements", Proceedings, American Concrete Institute, Vol. 14, pp. 366-373, 1918

The objectionable features of longitudinal and transverse cracks in portland cement concrete pavements laid on clay soils are mentioned. A pavement cross section involving the use of an impervious bituminous wall is suggested which will prevent the entrance of "outside moisture" and thus nullify or reduce the effect of frost action.

MACKINTOSH, A., "Progress Report of an Investigation of Frost Action in Soils", Proceedings, International Conference on Soil Mechanics and Foundation Engineering, Harvard University, Vol. 2, pp. 260-262, 22-26 June 1936

A description of the cold room and equipment for temperature measurement at Harvard University and progress in a determination of the magnitude of force which is associated with the growth of ice in soil.

MADDREN, A. G., "Smithsonian Exploration in Alaska in 1904", Smithsonian Miscellaneous Collections, Vol. 49, No. 1741, pp. 42-44, 1907

The author quotes Tyrrell's hypothesis on the mode of formation of crystosphenes (underground "wedges" or sheets of clear ice) found in the Klondike country.

MAIL, G. A., "Soil Temperatures at Bozeman, Montana, During Subzero Weather", Science, Vol. 83, No. 2163, p. 574, 12 June 1936

A brief discussion and graphical presentation of air and soil temperatures at depths of 0, 3 and 6 ft for the period commencing 25 January 1936 during which time Bozeman experienced its coldest and most extended period of subzero weather ever recorded.

MAMANINA, L., "The Effect of Insulating Layers on the Rise of Capillary Moisture in Heavy Loams", Pochvovedenie (Pedology) (Moscow), 1944, (2-3), 101-5 -- In Russian with English summary. Road Abstracts, Vol. 13, No. 3, Abst. No. 173, p. 34, 5 March 1946

Results of laboratory experiments on the effectiveness of layers of gravel and sand in preventing the rise of capillary moisture in heavy loams.

MATTIMORE, G. S. and RAHN, G. A., "Research on Concrete Disintegration", Proceedings, American Society for Testing Materials, Vol. 35, Pt. 2, Technical Papers, pp. 410-420, 1935

The authors present data on air temperatures and soil temperatures at 1-ft depth for the years 1930 to 1934, in northern Pennsylvania and show a correlation between freezing and thawing and concrete condition of 45 test culvert headwalls.

MEYER, E. V., "Conference Report on Porous (Cellular) Concrete", First International Congress for Concrete and Reinforced Concrete, Liege, Vol. 2, Question VI-9, pp. 139-144, 1930 -- In French with English summary.

Description of a porous lightweight concrete used for insulating purposes. Charts show the coefficient of conductivity and compressive strength characteristics.

MCCLAIN, C. W., "Combating Frost and Drainage Problem", Proceedings, 23rd Annual Road School, Purdue University, Engineering Bulletin, Vol. 2, No. 3, Extension Ser. No. 39, pp. 57-58, May 1937

A discussion of a general nature on F. C. Lang's paper in same publication. No data are given.

MCCOLLOCH, J. W. and HAYES, W. P., "Soil Temperature and Its Influence on White Grub Activities", Ecology, Vol. 4, No. 1, pp. 29-36, January 1923

The authors, in their study of white grub activities, obtained daily soil temperatures at Manhattan, Kansas, at depths of 1 to 6 ft from 1 March 1920 to 31 December 1921. Although a mild winter with no soil freezing, the temperature data are of general interest for the locality.

MCCOOL, M. M. and WHEETING, L. C., "Movement of Soluble Salts Through Soils", Journal of Agricultural Research, Vol. 11, No. 11, pp. 531-547, 10 December 1917

Migration of salts in soils from regions of higher to lower concentrations and with movement of soil are discussed.

Determination of salt concentrations was made by the freezing point method.

MCLEOD, N. W., "Soil Science Applied to Subgrade and Base Course Design", Canadian Engineer, Vol. 77, No. 5, pp. 5-6, with discussion on pp. 52 and 54, August 1939

A review of published theories on the mechanics of frost heave constitute a portion of this article.

MEINZER, O. E., "The Occurrence of Ground Water in the United States", U. S. Geological Survey Water Supply Paper, No. 489, pp. 30-63, 1923

The author describes various types of water tables; the capillary fringe; the capillary rise; and the yield and water retention in various types of soils.

MICHIGAN STATE HIGHWAY DEPARTMENT, "Subgrade Soil Exhibit", 29th Annual Convention and Exposition, American Road Builders Association, 11 pp., January 1932

A description of capillary experiments, drainage experiments, discussion of typical field conditions and grade-design measures for elimination of frost heaving and exhibit of frozen soil specimens.

MICHIGAN STATE HIGHWAY DEPARTMENT, "Field Manual of Soil Engineering", Revised Ed.; pp. 64, 77-82, 106-109, February 1946, Lansing, Michigan

Frost heave excavation, frost heave; capillary action, free water, collection of water in voids, textural changes, frost boils, spring

breakup and location, investigation, and inspection for preventing heaves.

MILLER, HERMAN H. and SMITH, DON N., "Methods for Prevention of Road Failures Due to Frost", Roads and Streets, Vol. 77, No. 6, pp. 219-221, June 1934

This article presents a plan for correcting frost heaves in roads in service by digging 1-ft-diameter by 2-ft-deep holes at 4- to 8-ft centers in the road and backfilling with pea gravel and calcium chloride. Good results are claimed.

MISSOURI STATE HIGHWAY COMMISSION, "Soils Manual", pp. 130-133, 1948, The Commission, Jefferson City, Mo.

A discussion of fundamental concepts of the freezing and heaving phenomena, probable location of frost boils, reduction in bearing value during the frost melting period, and methods for overcoming the detrimental effects of frost-heaving subgrades.

MOFFIT, F. H., "Geology of the N. and Grand Central Quadrangles-Alaska", U. S. Geological Survey Bulletin No. 553, pp. 53-54, 1913

Restatement of Tyrrell's description of "Crystosphenes or Buried Sheets of Ice in the Tundra of Northern America".

MOORE, W. L., "Descriptive Meteorology", pp. 107-114, 1910, D. Appleton and Co., New York

A comprehensive treatise on meteorology. Included is a discussion of "Frosts: Influence of Soil and Vegetation on Minimum Temperatures", a major portion of which is devoted to conditions under which frost occurs in bogs and the effect of sanding or flooding bogs to prevent frost.

MOOS, A. VON, "The Part Played by the Foundation in Road Failures", Strasse u. Verkehr, 1943, 29 (1) 1-7; (2) 21-9; Road Abstracts, Vol. 12, No. 3, Abst. No. 118, p. 25, March 1945

Purpose of foundation or base, effect of faulty construction and criteria for detecting materials or conditions likely to cause trouble. Special reference is given to prevention of frost damage.

MORTON, J. O., "Soil Profile Field Methods in New Hampshire", Proceedings, International Conference on Soil Mechanics and Foundation Engineering, Harvard University, Vol. 1, p. 247, 22-26 June 1936

A brief description of soil survey methods in New Hampshire.

MORTON, J. O., TREMPER, B., STOKSTAD, O. L. and CASAGRANDE, L., "Prevention of Detrimental Frost Heave", Proceedings, Highway Research Board, Vol. 18, Pt. 2, pp. 356-365, 1938

A symposium reviewing the theory of frost action; measures in use in New Hampshire, Washington, Michigan and Germany for preventing detrimental frost action; and suggestions for new research.

MOTL, C. L., "Study of Laws and Practices Applying to Special Load Limitations to Prevent Pavement Damage", Progress Report of Subcommittee

No. 2, Maintenance Committee, American Association of State Highway Officials, 1947

Status of enforcement of load limit laws and results of load bearing tests on Minnesota pavements in early fall and in early spring during the frost melting period.

MOZLEY, A., "Frozen Ground in the Sub-Arctic Region and Its Biological Significance", Scottish Geographical Magazine, Vol. 53, No. 4, pp. 266-270, July 1937

Data on mean annual air temperatures, depth of snow cover, depth of perennially frozen ground and ground temperatures in northern Asia, and minor reference to the existence of plant and animal life in those regions.

MULLER, SIEMON WM., "Permafrost or Permanently Frozen Ground and Related Engineering Problems", U. S. Geological Survey, Special Report, Strategic Engineering Study No. 62, Prepared for Military Intelligence Division, O.C.E., U. S. Army, 1945, 2nd printing, 231 pp. Reprint by J. W. Edwards Inc., Ann Arbor, Michigan, 1947

A comprehensive treatment of ice and permafrost. Of interest pertaining to frost action are: lag of ground temperatures behind air temperatures; fundamental principles governing formation of ice in soil; freezing temperatures of salt solutions; heat conductivity of soils; and swelling of ground during freezing.

MULLIS, IRA B., "Illustrations of Frost and Ice Phenomena", Public Roads, Vol. 11, No. 4, pp. 61-79, June 1930

The author illustrates various forms of detrimental frost phenomena and discusses and presents data on volume change-temperature change characteristics of water and ice; pressure effects due to frost action; direction of heat radiation; size of soil particle; and the amount of water available.

MUSKAT, M. and WYCKOFF, R. D., "The Flow of Homogeneous Fluids Through Porous Media", First Edition, 1937, 782 pp. McGraw-Hill Book Co., Inc., New York

This book consists of the following: Part I -- Foundations; Part II -- Steady-State Flow of Liquids; Part III -- The Nonsteady-State Flow of Liquids; Part IV -- The Flow of Gases through Porous Media; the subject matter of this treatise, the flow of homogeneous fluids through porous media while distinctly limited by the qualifications "homogeneous" and "porous", is nevertheless sufficiently wide in scope to find application in many branches of applied science. In such fields as ground-water hydrology encompassing the provision and maintenance of water supplies, irrigation, and drainage problems, and petroleum engineering involving the production of gas and oil from their underground reservoirs, the applications are evidently of basic importance. Equally important are applications to specific problems encountered in civil engineering, agricultural engineering and many industries.

NATIONAL RESEARCH COUNCIL OF CANADA, "Soil Temperatures in Canada -- Observations of Soil Temperatures", February 1937, Ottawa  
 Observations were made from 1894 to 1900 at McGill University. Thermometers were placed at depths from 4 in. to 9 ft in sandy soil. Other observations were made at Guelph, Ontario from 1930 to 1932 and at the University of Saskatchewan from 1921 to 1923 and from 1929 to 1934. Some of these results have been taken from other papers. The effect of snow, rain and air temperatures on soil temperatures is discussed at length. The frost penetration and depth of water mains in various Canadian cities is given including Calgary, Edmonton, Moose Jaw, Regina, Winnipeg, Windsor, Brantford, Chatham, and Ottawa. Permafrost in the Hudson Bay area and the Klondike region is stated to be over 200 ft deep. The maximum depth of thaw is generally 6 in. to 10 ft from the surface.

NATURE, "The Permanently Frozen Soils of Russia", Nature (London), Vol. 123, No. 3106, pp. 741-742, 11 May 1929

Abstract of a monograph "Everfrozen Soil in the Boundaries of USSR", by M. Sumgin. The Far Eastern Geophysical Observatory, Vladivostok, 1927. Gives definition of perpetually frozen soil, shows its geographical distribution, and depth; correlates depth of snow cover with seasonal fluctuations of temperature in soil; cites three different types of temperature distribution in permafrost; discusses the origin of permafrost and describes the hydrological conditions of the permafrost regions.

NICHOLS, D. A., "Solifluction and Other Features in Northern Canada Shown by Photographs from the Air". Transactions, Royal Society of Canada, Third Ser., Vol. 26, Sec. 4, pp. 267-275, May 1932

Description of various aspects of solifluction (soil flow) in sub-polar regions due to effect of freezing and thawing. Also includes description of soil polygons, soil stripes and such topographic features as raised beaches, eskers, and faults.

NIKIFOROFF, CONSTANTIN, "Perpetually Frozen Subsoil of Siberia", Soil Science, Vol. XXVI, No. 1, July 1928, pp. 61-79

This article discusses the location, thickness and temperature of permafrost, particularly in the vicinity of Yakutsk, Russia. The well of Shergeen at Yakutsk is stated to be 382 ft deep and the temperature at the bottom to be  $-3^{\circ}\text{C}$ . A hypothesis as to the origin of permafrost is discussed. It is pointed out that the climatic conditions resulting in excess of cold may cause the permafrost. The other theory points out that permafrost may have been caused by glacial action. There is a discussion of soil blisters and ice caverns. It is pointed out that agriculture by the Yakuts has been successful in spite of the fact that the growing season is only 100 days long. Of course, during the growing season, the sun shines from 21 to 22 hours per day. Dairying is the principal agricultural pursuit. It is pointed out that perpetually frozen subsoil in North America has received very little discussion in technical literature. A series of maps and graphs illustrating the author's dissertation are included.

NUNN, E. H., "Subgrade Protection and Winter Paving on Access Roads", Calcium Chloride Association News, Vol. 8, No. 4, pp. 4, 5, 10, 1 August 1942

Brief description of the use of calcium chloride to prevent freezing of the subgrade in winter construction.

OSTERBERG, J. O., "A Survey of the Frost Heaving Problem", Civil Engineering, Vol. 10, No. 2, pp. 100-102, February 1940

A description of damage due to frost heave and review of the mechanics of frost heave; the relationship between grain size and capillarity and heaving; and practical means of preventing frost heaving.

PALMER, C. A., "Permafrost Problems", Civil Engineer Corps Bulletin, Vol. 2, No. 17, April 1948, Bureau of Yards and Docks, U. S. Navy

Report consists primarily of a list of precautions that must be taken when building in permafrost areas (list has 16 precautions) -- i.e., variation in supporting power between frozen and thawed ground, the ground under buildings on permafrost tends to freeze less and thaw more thereby effectively lowering the permafrost table, etc. The origin of "Nalyeds" and ice mounds are discussed. The necessary research investigations that should be carried on are discussed. Discussion of personnel and field and laboratory equipment necessary for the research is included.

PALMER, L. A. and THOMPSON, J. B., "Pavement Evaluation by Loading Tests at Naval and Marine Corps Air Stations", Presented at the 27th Annual Meeting of the Highway Research Board, 1947

Data of interest relative to studies of frost action are existing soil moisture contents correlated with soil type.

PARADIS, ALPHONSE, "Foundations and Protection Against Frost Heaving", Canadian Engineer, Vol. 67, No. 16, pp. 21-24, 16 October 1934

A description of field experiments involving the use of "sand cushions" up to 12 in. in depth, and a discussion of the use of sand cushions as bases under roads to prevent frost heaving.

PATERSON, T. T., "The Effects of Frost Action and Solifluxion Around Baffin Bay and in the Cambridge District", Quarterly Journal of the Geological Society of London, Vol. 96, No. 381, pp. 99-130, April 1940

Description of frost cracking, mud and stone polygons, and solifluxion (soil flow); and discussion of the origin of frost cracks, theories of the formation of polygonal structures, and mechanics of solifluxion.

PATTEN, H. E., "Heat Transference in Soils", U. S. Dept. of Agriculture, Bureau of Soils, Bulletin No. 59, 1909, 54 pp.

The results of laboratory experimental study and review of literature on the thermal properties of soils. Presented are experimental and derived data on heat of wetting, diffusivity rate, relation between surface area, moisture film, and heat conductivity, and diffusivity, for 7 soils ranging from

coarse quartz to clay.

PENNSYLVANIA ROAD BUILDER, "Preventing Detrimental Frost Heaving", Pennsylvania Road Builder, Vol. 15, No. 9, pp. 4 and 15, September 1942  
Brief discussion on the use of calcium chloride in soils and soil-aggregate mixes to prevent detrimental frost action.

PLUMMER, F. L. and DORE, S. M., "Soil Mechanics and Foundations", pp. 131-140, 353-357, 1940, Pitman Publishing Corp., New York  
Heaving of highway slabs, ice segregation, effect of texture, effect of colloidal material, movement of water to form ice crystals, effect of consolidation, effect of water table level, effect of surface load, unfavorable subgrade conditions, thawing of frozen soil, frost in foundations, typical frost heaving example, and prevention of frost heaving are discussed in this text.

POPULAR SCIENCE MONTHLY, "Revolt of the Earth: Permafrost Tests Ingenuity of Arctic Builders", Popular Science Monthly, Vol. 149, pp. 126-129, November 1946  
Popular discussion of difficulties of building in permafrost regions.

PORSILD, A. E., "Earth Mounds in Unglaciated Arctic Northwestern Alaska", Geographical Review, Vol. 28, No. 1, 1938  
Origin of mounds -- hypotheses covered are (1) by hydraulic pressure, cracks caused on surface with possible steady seepage after-ward; (2) so-called "local upheaval" on low marginal plains. Descriptions and photographs of "pingos" with cross section of one, also discussion of remnants and their cause included. Local upheaval is due to expansion of water as downward freezing progresses. Mention of cold storage vaults on "pingos" in Kotzebue region with discussion of their mode of origin.

PUBLIC WORKS MAGAZINE, "Soil Freezing and Frost Heaving", Public Works Magazine, Vol. 67, No. 2, pp. 41-42, February 1936  
A synopsis of a report by G. Beskow, "Tjälbildningen och Tjällyftningen", Statens Veginstitut, Meddelande 48, Sveriges Geologiska Undersökning, Ser. C, No. 375, Stockholm, 1935, The synopsis appeared in Road Abstracts. (See reference under Beskow.)

RAMBAUT, A. A., "Results of Meteorological Observations", Also Underground Temperatures in Twelve Years, 1898-1910. Radcliffe Observations, Radcliffe Observatory, Oxford, Vol. 51, pp. 103-215, 1916, Oxford University Press, London.  
This publication describes apparatus and methods of reducing observations of earth temperatures, discusses observations, computation of thermal diffusivity of gravel in which thermometers were placed, and amplitudes of temperature waves. Charts showing mean monthly temperatures of the ground for various depths are included.

RAVIN, H. H., "Frost Damage on Roads", Dansk Vjtidsskr. 1939, 16 (4), pp. 142-148; Road Abstracts, Vol. 7, No. 3, Abst. No. 81, pp. 37-38, April 1940

A general review of the theory of frost action and the many and varied means of preventing damage due to frost. Some of the means of prevention mentioned are (1) replacement with coarser soil; (2) use of protective courses; (3) use of insulating courses of brush, straw or hay; (4) permitting rapid freezing by immediate removal of snow; (5) the use of admixtures; and (6) drainage.

RAVIN, H. H., "The Origin of Frost Damage and Methods of Combating It", Dansk Vjtidsskr, 1940, 17 (2), pp. 40-52, (3) 90-97, (5) 151-171; Road Abstracts, Vol. 14, No. 4, Abst. No. 262, p. 48, 1 April 1947; Highway Research Abstracts, No. 141, p. 6, May 1947

A discussion on the mechanics of frost heaving; depth of frost penetration; amount of heaving; effect of surface loading, grain size of soil, and temperature on heaving; laboratory and field tests, effectiveness of granular bases, insulation (brush, moss, etc); drainage and chemical treatment of soils.

ROADS AND STREETS, "Simple Method of Preventing Spring Breakup of Roads", Roads and Streets, Vol. 97, No. 10, p. 81, October 1944

Description of method of introducing calcium chloride and pea gravel in holes in subgrade to prevent spring breakup.

ROBERTS, M., "Notes on the Action of Frost on Soil", Journal of Geology, Vol. 11, No. 3, pp. 314-317, April-May 1903

Description of ground surface hoar frost (needle ice, Swedish pipkrake) formed in the Puget Sound area from 13 February to 18 February 1903 with ground temperatures as low as 24° F. Includes four photos showing ice formed in six layers ranging in height from 3/8 to 1 inch.

ROOT, W. H., "Vertical Drainage" from Highway Maintenance Performance Items, Summer 1947. An unpublished report of highway maintenance items assembled by Public Roads Administration.

Experience in the use of deep vertical drains to prevent frost heaving.

ROWAT, R. M., "Control of Frost Heave", Proceedings, 19th Annual Meeting, Highway Research Board, December 1939, pp. 464 to 466

The author describes the use of salt in the prevention of frost heave on railroad tracks. Frost heave will not take place if the soil water in a susceptible area does not freeze. Several methods of applying the salt to the roadbed are discussed, but the important factor is to apply the salt early enough so that it may be thoroughly distributed over the susceptible area by the time freezing starts. The author suggests the use of salt as an admixture in subbase courses of highways as a frost control measure.

ROZARKI, G., "Stone-Centered Polygons on the Rock Ledge Bordering the Genesee River at Letchworth Park, N. Y.", *Journal of Geology*, Vol. 51, pp. 330-341, 1945

Author describes polygons in some detail, slabs of shale 1 ft. in diameter, surrounded by fresh fragments 3 in. long, 1/4 in. thick, 3 in. wide standing on end (photograph included). Bedrock found 6 in. or less below surface. Origin discussed. Water flowing over thinly bedded shale, upon freezing, causes disintegration and separation of bedrock. Subsequent freezing causes further disintegration. End product is mud (silt), but further weathering causes further formation of stone-centered polygons. One winter appears to be minimum period of formation, at Letchworth Park, polygons formed in 4 years with 300 days of freezing and thawing temperatures.

RUCKLI, ROBERT, DR., "Frost Damage in Highway Subgrades" *Strasse und Verkehr*, Vol. 29, No. 19-22, 24-25, 17 September, 10 December 1943 (Translated by H. B. Edwards, Engineer Dept. Research Center, U. S. Waterways Experiment Station, Vicksburg, Miss., August 1944). Note: This article is itself a German translation of a French article, "Gelivite des Sols et Fondation des Routes" by Dr. A. Spicky of Lausanne University. Published in book form by the Societe du Bulletin Technique de la Suisse Romande)

A long and informative article arranged in 7 parts: (1) Types of ice in soil; (2) The mechanics of frost heaving; (3) Frost conditions in Switzerland; (4) Temperature conditions in the soil; (5) Frost penetration in the soil; (6) Theory of frost heaving; and (7) Field experiments.

SCHAIBLE, L., "Frost Damage", *Bautechnik*, 1941, 19 (49), pp. 528-31; (50/51), pp. 541-3; *Road Abstracts*, Vol. 10, No. 3, Abst. No. 163, pp. 37-38, March 1943; *Highway Research Abstracts*, No. 99, p. 7, April 1943  
Discussion of factors that enter into the action of frost in soil and causes of frost damage based chiefly on experience gained in Silesia in winter of 1939-40.

SCHAIBLE, L., "The Repair of Frost Damage", *Strasse*, 1942, 9(17/18), pp. 173-6; *Road Abstracts*, Vol. 12, No. 1, Abst. No. 28, p. 6, 2 January 1945; *Highway Research Abstracts*, No. 118, p. 4, March 1945  
Comparison of effectiveness and cost between replacing unstable subgrade material and using the old road surfacing as a foundation and rebuilding the road at a higher level.

SCIENCE NEWS LETTER, "Russia's Frozen Expenses Have Lessons for U. S.", *Science News Letter*, Vol. 42, No. 3, p. 39, 18 July 1942  
Brief general interest article stressing the need for more information on perpetually frozen ground for application to problems in Canada and Alaska.

SEMIKIN, F. M. and MIKHALEV, P. F., "Formation of Periodic Ice Streaks During Soil Freezing", *Comptes Rendus (Doklady) de l'Academie des Sciences, USSR*, 1937, 17 (8) 405-7. (in English). *Science Abstracts*,

1938, 41 (484), 356. Road Abstracts, Vol. 5, No. 7, Abst. No. 388, p. 110, October 1938

By using an analogy between the differential equations of diffusion and heat conduction, a law has been obtained giving the spacings between ice-streaks in frost heaving. The law is said to be in accordance with the observations of Taber.

SHANKLIN, G. B., "The Effects of Moisture on the Thermal Conductivity of Soils", Transactions, American Institute of Electrical Engineers, Vol. 41, pp. 94-101, 1922

This article presents a review of previous data on heating by underground cables; gives data showing the effect of soil moisture on the thermal conductivity of soils in dissipating heat generated within the cables; and detailed description of apparatus and test methods for determining the thermal conductivity of soils at different moisture contents. Bibliography.

SHANNON, W. L., "Frost Investigations at Dow Field, Bangor, Maine", Proceedings, Highway Research Board, Vol. 24, pp. 71-86, 1944

Design of bases on soils affected by frost; definition and description of frost action; weather, soils and frost-heaving data; and accelerated traffic tests on flexible and rigid pavements at Dow Field.

SHANNON, W. L., "Prediction of Frost Penetration", Journal, New England Water Works Association, Vol. 59, No. 4, pp. 356-363, December 1945

Data on and discussion of factors influencing frost penetration; the freezing index (with an approximate formula for computing F.I.); thermal properties of soils; depth of frost penetration and means of computing it; correlation between depth of frost penetration and freezing index; and freezing index frequency.

SHANNON, W. L. and WELLS, W. A., "Tests for Thermal Diffusivity of Granular Materials", Presented at the 50th Annual Meeting of the American Society for Testing Materials, 16-20 June 1947

Description of apparatus and test methods, analyses, and results of tests to determine thermal diffusivity of a number of different granular materials.

SHARP, R. P., "Ground-Ice Mounds in Tundra", Geographical Review, Vol. 32, No. 3, 1942

Description of ground ice mounds in Wolf Creek region; photographs and cross-sectional sketches included. Mode of origin discussed may be due to hydraulic pressure or of Porslid's "upheaval" type; definitely not entombed ice because of surface indications of upheaval. Discussion of cycles observed in the development of ice mounds and their relation to the tundra topography produced; knobs and depressions more or less mantled by vegetation contained in report. Ground-ice mounds should be considered along with solifluction, frost heaving, and "Palsen"

formation in the development of tundra topography.

SHARP, R. P., "Soil Structure in the St. Elias Range, Yukon Territory", *Journal of Geomorphology*, Vol. 5, pp. 274-301, 1942

Investigations carried on in Wolf Creek area of St. Elias Range, Alaska. Descriptions with sketches or photographs include those of stone nets, stone garlands, stone stripes, earth stripes, and earth hummocks. The descriptions are followed by a study of the origin of the various features. Frost action important in the formation of each of the above structures with slope determining the specific shape of various stone and earth features. Age of structures appears to be about 100-200 yrs.; however, some may be 4000 yrs. Stone nets occur on flat or very gently sloping ground; stone garland on slopes of 5-15 degrees, stone stripes on slopes of from 7 to 30 degrees. Fines elevated by the formation of ice wedges below and within them. Earth stripes are of unknown origin except for the fact that they are frost phenomena. Earth hummocks are caused by the flow of material away from other areas that froze somewhat earlier. They occur on the flat or slopes up to 20 degrees. Ninety references cited in body of report. Good sketches and photographs describing phenomena.

SHARPE, C. F. S., "Landslides and Related Phenomena", A Thesis, 1938, 137 pp., Columbia University, New York

A purely descriptive review based on a field study of a wide range of typical cases and an extensive review of the literature, of the present state of knowledge of mass movements of soil and rock. It includes a section on "Frost Action and Solifluction (soil flow)" and an extensive bibliography.

SKELTON, R. R., "Field Observations of Frost Heave", *Proceedings, Purdue Conference on Soil Mechanics and Its Applications, Purdue University, Symposium on Frost Action*, pp. 460-470, 2-6 September 1940

Methods of observation and results of field observations of frost heave and related factors on a portland cement concrete pavement in New Hampshire.

SLATE, F. O., "Use of Calcium Chloride in Subgrade Soils for Frost Prevention", *Proceedings, Highway Research Board*, Vol. 22, pp. 422-441, 1942

Methods used and results of field application of calcium chloride in pockets cut through road surface and base; results of field and laboratory studies of migration of chloride; and its effectiveness in preventing frost heave.

SLATE, F. O., "Use of Calcium Chloride in Subgrade Soils for Frost Prevention", *Calcium Chloride Association News*, Vol. 9, No. 1, p. 5, 1 February 1943

Condensed synopsis of a paper appearing in *Proceedings, Highway Research Board*, Vol. 22, pp. 422-441, 1942.

SLESSER, CHARLES, "The Migration and Effect on Frost Heave of Calcium Chloride and Sodium Chloride in Soil", *Purdue University, Engineering*

Bulletin, Vol. 27, No. 4 (Research Ser. No. 89, Highway Research Bulletin 11), July 1943, 168 pp.

Survey of literature, comprehensive field and laboratory studies of migration of chloride salts and laboratory studies of frost heave. Bibliography.

SMIRNOFF, A., "Soil Temperatures and Cable Rating", Electrical World, Vol. 82, No. 9, pp. 438-439, 1 September 1923

The author presents year-round temperature data of soil at depths of 18, 27 and 36 in.; mean air temperatures; rainfall in inches and solar radiation in g. calories per sq. in. for Washington, D. C. and constructs soil temperature-cable rating charts.

SMITH, A., "Seasonal Subsoil Temperature Variations", Journal of Agricultural Research, Vol. 44, No. 5, pp. 421-423, 1 March 1932

Includes soil and air temperature data taken at Davis, California and a discussion of the range of soil temperatures of various depths.

SMITH, ALFRED, "Daily and Seasonal Air and Soil Temperatures at Davis, California", Hilgardia, Vol. 4, No. 3, pp. 77-112, May 1929

Observed air and soil temperatures at Davis, California. This reference is given because it describes the installation of thermometers. Winter temperatures of the soil did not fall below freezing.

SMITH, ALFRED, "Effect of Paper Mulches on Soil Temperature, Soil Moisture, and Yields of Certain Crops", Hilgardia, Vol. 6, No. 6, November 1931

In this investigation, particular emphasis has been placed on soil temperature, soil moisture, and the effects of different types, grades, and colors of paper. Certain crops were used as indicators and the effect of different papers and methods of laying them carefully noted.

SMITH, ALFRED, "Comparisons of Daytime and Nighttime Soil and Air Temperatures", Hilgardia, Vol. 4, No. 10, December 1929

A discussion of the relationship between the rate of percolation and soil temperature and a charted summary of soil temperatures. Air temperatures were obtained by means of a thermograph placed in a U. S. Weather Bureau shelter and soil temperatures were automatically recorded every 15 minutes by means of a Leeds and Northrup temperature recorder with electrical resistance thermometers placed at several depths in an area that was kept free of growing vegetation. Details concerning the area at Davis, California were described in Hilgardia, Vol. 4, No. 3, May 1929.

SMITH, A., "A Contribution to the Study of Interrelations Between the Temperature of the Soil and of the Atmosphere and a New Type of Thermometer for Such Study", Soil Science, Vol. 22, No. 6, pp. 447-457, December 1926

Factors influencing soil temperature are summarized and

temperature interrelations between soil and atmosphere for daytime and nighttime are given. Bibliography.

SMITH, H. W., "Frost Damage to Sealed Surfaces in Southland", Proceedings, New Zealand Institution of Engineers, Vol. 32, pp. 570-594, 1945-46; Highway Research Abstracts, No. 138, pp. 2-4, February 1947

Description of road surface failures due to frost action; mineralogical description of aggregates used; specific heat and thermal conductivity of various materials; soil temperatures and computation of time required for frost to penetrate bases of various materials and thickness.

SMITH, W. O., "The Thermal Conductivity of Dry Soil", Soil Science, Vol. 53, No. 6, pp. 435-459, June 1942

Experimental procedure on monolith samples. Thermal conductivity, porosity, volume weight and specific gravity data on air-dry monoliths of several soils; thermal transfer in structureless soils and in structured soils; approximate calculation and values of the thermal structure factor; and thermal conductivity of peat solids.

SMITH, W. O. and BYERS, H. G., "The Thermal Conductivity of Dry Soils of Certain of the Great Soil Groups", Proceedings, Soil Science Society of America, Vol. 3, pp. 13-19, 1938

The thermal conductivity of dry soils and its relation to volume weight and porosity; and the conductivity of different soils of the various great soil groups. An equation is developed by means of which thermal conductivity can be computed.

SMITH, W. O., "Thermal Conductivities in Moist Soils", Proceedings, Soil Science Society of America, Vol. 4, pp. 32-40, 1939

A supplement to a previous paper by the author on thermal conductivity in dry soils (Proceedings, Soil Science Society, Vol. 3, pp. 13-19, 1938). Experimental data are given for four soils. Of particular interest in the experiment was the movement of moisture from the warm to the cool side of the sample undergoing conductivity test.

SMITHSONIAN PHYSICAL TABLES, "Density and Volume of Water", Smithsonian Physical Tables, Smithsonian Miscellaneous Collections, Vol. 71, p. 120, 1921

Table showing the density and volume of water by degrees C from  $-10^{\circ}\text{C}$  to  $210^{\circ}\text{C}$ .

SOURWINE, J. A., "A Method of Analysis of Data on Frost Occurrence for Use in Highway Design", Public Roads, Vol. 11, No. 3, pp. 51-60, May 1930

A statistical study of intensity duration and frequency of low temperature occurrence over a period of years and a suggested method by which climatological records may serve as a guide in the determination of probable ground freezing occurrence. Discussed are: source of data; suitability of absolute minimum temperatures; critical air temperature for ground freezing;

critical depth of freezing; critical soil temperature for freezing;  
relation between minimum temperature in air and in soil;  
frequency of minimum temperatures; critical value of lowest  
monthly average of daily minimum temperature; effect of precip-  
itation; and effect of duration of cold.

**SOURWINE, J. A., "Art of Preparing an Earthen Foundation", U. S. Patent No. 2, 162, 185, 13 June 1939**

A patent covering the use of any liquid other than water and carrying in suspension less than 1-1/2 percent of solid matter, having a freezing point lower than water and possessing the physical capacity to form a thin capillary film for the purpose of incorporating with soil to insure stability against ground freezing and ground heaving. The claimant specifically exempts bituminous materials, "sulfide wastes", or residual liquors, calcium chloride and sodium chloride. The method of preparing the foundation is specified.

**STOKSTAD, O. L., MORTON, J. O., TREMPER, B., and CASAGRANDE, L., "Prevention of Detrimental Frost Heave", Proceedings, Highway Research Board, Vol. 18, Pt. 2, pp. 356-365, 1938**

A symposium reviewing the theory of frost action; measures its use in New Hampshire, Washington, Michigan and Germany for preventing detrimental frost action; and suggestions for new research.

**STRATTON, J. H., "Military Airfields: A Symposium. Construction and Design Problems. Design of Drainage Facilities", Transactions, American Society of Civil Engineers, pp. 684, 764, 778, 781, 783, 1945**

Brief statements on design of military airfield pavements for frost action are included in the general discussion.

**SWANBERG, J. H., "Temperature Variations in a Concrete Pavement and the Underlying Subgrade", Proceedings, Highway Research Board, Vol. 25, pp. 169-180, 1945**

Temperature variations in concrete and the underlying subgrade over a 5-year period in Minnesota.

**SWANBERG, J. H. and HANSEN, C. C., "Development of a Procedure for the Design of Flexible Bases", Proceedings, Highway Research Board, Vol. 26, pp. 44-57, 1946**

The results of field and laboratory studies to establish the relationship between field performance of flexible type bases and bearing values obtained in the laboratory. Included are significant data on soil moisture and density changes.

**TABER, STEPHEN, "The Growth of Crystals Under External Pressure", American Journal of Science, Fourth Ser., Vol. 41, No. 246, pp. 532-556, June 1916**

Discusses the phenomena associated with growth of crystals in an alum solution, and in a copper sulphate solution, and relates such crystal growth to the growth of ice crystals

associated with frost heave.

TABER, S., "Ice Forming in Clay Soils Will Lift Surface Weights", Engineering News-Record, Vol. 80, No. 6, pp. 262-263, 7 February 1918

The author describes the results of placing metal weights on wet sand and on wet clay and freezing during cold nights.

TABER, STEPHEN, "Surface Heaving Caused by Segregation of Water Forming Ice Crystals", Engineering News-Record, Vol. 81, No. 15, pp. 683-4, 10 October 1918

A discussion of articles by J. L. Harrison, Engineering News-Record, Vol. 80, No. 9, pp. 418-420, 28 February 1918, and by C. D. Norton, Vol. 80, No. 22, p. 1058, 30 May 1918, in which Taber disputes their claims and presents his hypothesis on the formation of ice layers and the cause of frost heave.

TABER, STEPHEN, "Frost Heaving", Journal of Geology, Vol. 37, No. 5, pp. 428-461, July-August 1929

Taber describes the experimental procedure followed: gives an explanation of ice segregation; and discusses the following factors which influence frost heaving; size and percentage of voids in soil, size of particle, water content of soil, and rate of cooling. He also discusses depth of freezing, direction of cooling, external pressure, crushing strength of ice, differential heaving, effects of thawing and refreezing, and shrinkage of clays caused by ice segregation.

TABER, S., "The Mechanics of Frost Heaving", Journal of Geology, Vol. 38, No. 4, pp. 303-317, May-June 1930

A tentative hypothesis explaining the mechanics of frost heave. This article supplements that given in Journal of Geology, Vol. 37, No. 5, pp. 428-461, July-August 1929

TABER, S., "Freezing and Thawing of Soils as Factors in the Destruction of Road Pavements", Public Roads, Vol. 11, No. 6, pp. 113-132, August 1930

A summary of Taber's comprehensive studies of frost action in soils. Apparatus and test methods are described. Freezing effects in closed and open systems; direction of growth of ice crystals; grain size; soil composition, water supply, rate of cooling; effect of load pressure; the mechanics of frost heaving in open systems; and freezing and thawing of soils under pavements are discussed.

TABER, S., "Discussion on Frost Heaving", (Abstracted), Proceedings, Highway Research Board, Vol. 11, Pt. 1, pp. 173-7, 1931

A summarization of Taber's hypothesis on the mechanics of frost heaving, and discussion of the Benkelman and Olmstead theory.

TABER, STEPHEN, "Perennially Frozen Ground in Alaska; Its Origin and History", Bulletin of the Geological Society of America, Vol. 54, No. 10,

1943, pp. 1433-1548

Comprehensive treatise on permafrost. Principal subject matter includes: extent of permafrost; present climate in Alaska; vegetation, geological processes; Quaternary geology; perennially frozen ground; ground ice. Illustrated. Bibliography.

TERZAGHI, C., "The Science of Foundations -- Its Present and Future", Transactions, American Society of Civil Engineers, Vol. 93, pp. 291-293, 1929

An analysis of the conditions required for producing the lifting effect caused by the adfreezing of soil to piers.

TERZAGHI, KARL and PECK, RALPH B., "Soil Mechanics in Engineering Practice", 1948, John Wiley & Sons, Inc., New York

Part A deals with the physical and mechanical properties of homogeneous specimens of undisturbed and remolded soils. It discusses those properties which serve as convenient criteria for distinguishing between different soils and provides instructions for describing soils adequately. It also deals with those soil properties that have a direct bearing on the behavior of soil masses during and after construction operations. Part B provides the reader with an elementary knowledge of the theories required for solving problems involving the stability or bearing capacity of soils or the interaction between soil and water.

All these theories are based on radically simplifying assumptions regarding the mechanical and hydraulic properties of the soils. Nevertheless, when properly applied, the results obtained by means of these approximate procedures are accurate enough for most practical purposes. Part C deals with the application of our present knowledge of soil behavior and of the theories of soil mechanics to design and construction in the field of foundation and earthwork engineering. The design of pavements for roads and airports is represented only by references in the Appendix because it constitutes an independent and highly specialized branch of earthwork engineering.

THOMAS, B. P., "Thawing Frozen Subgrades", Calcium Chloride Association News, Vol. 9, No. 1, pp. 8, 10, 1 February 1943

Review of experiences during wartime construction where calcium chloride was used to accelerate thawing of frozen subgrades.

THOMSON, W. A., "Soil Temperatures at Winnipeg, Manitoba", Scientific Agriculture (Canada), Vol. 15, No. 4, pp. 209-217, December 1934

Describes the installation of electrical resistance thermometers at depths up to 15 ft.; presents soil temperature variation curves covering a three-year period; and discusses the effect of snow cover on soil temperature.

TUCK, RALPH, "Origin of the Muck-Silt Deposits at Fairbanks, Alaska", Bulletin of the Geological Society of America, Vol. 51, pp. 1295-1310, 1940

Introduction covers discussions of problems, description of district, mention of permanently frozen ground to depths of

200 ft, mentions location of frozen ground below muck deposits but in general not below silt deposits. Muck exists in valleys with the exception of Tanana River where gravel flats are exposed, but a lower muck horizon exists below present stream gravel. Relation of silt to glaciation and rock floor of glaciers and indications of climate and vegetation from deposits of muck and silt are discussed in report.

TYRRELL, J. B., "Crystosphenes or Buried Sheets of Ice in the Tundra of Northern America", *Journal of Geology*, Vol. 12, No. 3, p. 234, April-May 1904

Mr. Tyrrell presents theories which he thinks account for the formation of glaciers, the surface masses of ice formed each winter by the overflow of springs and ground ice. He suggests that the name "crystocene" (derived from the Greek words "ice" and "fountain") replace the name "glacier" and also suggests the name "crystosphere" (derived from the Greek words for "ice" and "wedge") for ground ice or the ice wedges existing below the ground surface. His theory for the formation of underground ice is that underground flows of water have come to the surface in the form of springs, "freeze at the surface and the ice continuing to form downward until, a few feet below the surface but still within the influence of the external low temperature, a plane of weakness is reached in the stratified frozen vegetation or alluvial deposit, such planes of weakness being generally determined by the presence of thin bands of silt or fine sand..... and there the main body of the ice wedge is formed". Location discussed is the Klondike country.

U. S. DEPARTMENT OF AGRICULTURE, "Climate and Man", Yearbook of Agriculture, Pt. 5, Climatic Data, with Special Reference to Agriculture in the U. S., pp. 664-1210, 1941

Charted and tabular data on temperature and precipitation up to 1938. Includes 46 charted maps of the U. S. as well as climatic summary tables, precipitation and temperature tables, special frost tables and supplementary climatic notes for each state.

U. S. NAVY, "Permafrost Must be Respected", Civil Engineer Corps Bulletin, Bureau of Yards and Docks, p. 123, Vol. 2, No. 18, May 1948

General rewrite of U. S. Army field experience in permafrost together with some outside information. Work covers Army's work at Ladd Air Force Base, Fairbanks. General information on permafrost included, i.e., types of vegetation, the significance of the various types, some preventative measures to be taken in permafrost areas, mention of the active and passive methods of dealing with permafrost. Sketches showing construction methods to be used are included, i.e., insulation, the various types of insulation, methods of placing insulation, methods of insuring flow of air beneath building.

U. S. WAR DEPARTMENT, "Airfield Pavement Design: Frost Conditions", *Ad Interim Engineering Manual for War Department Construction*, Pt. 12,

Chapt. 4, U. S. War Department, Corps of Engineers, Office. Chief of Engineers, July 1946, 10 pp.

Conditions affecting frost action; heaving; insulating materials; base composition requirements, and protection of subgrade for flexible and rigid pavements with examples of design for frost action.

U. S. WEATHER BUREAU, "Climatic Summary of the United States", Bulletin W, Sec. 1 to 105, 1930

Climatic data from the establishment of stations to 1930 inclusive. See also monthly summaries of weather data by states for climatic data from 1930 to present.

U. S. WEATHER BUREAU, "Average and Extreme Depth of Frost Penetration", Undated Maps.

Maps of the U. S. showing (1) extreme frost penetration, and (2) average annual frost penetration.

URQUHART, L. C., "Civil Engineering Handbook", 2nd Ed., pp. 627, 840, 1940, McGraw-Hill Book Co., New York

Expansion of earth on freezing, depth of frost penetration, and rate of change of temperature of water.

VISHER, S. S., "Climatic Laws", 1924, 96 pp., John Wiley and Sons, New York

This book contains 90 generalizations with numerous corollaries concerning the geographic distribution of temperature, wind and moisture. No specific data of value in the solution of the frost action problem is given.

WALLACE, ROBERT E., "Terrain Analysis in the Vicinity of Northway, Alaska with Special Reference to Permafrost", Permafrost Program Progress Report No. 3, July 1946, U. S. Dept. of Interior, Geological Survey

This report describes the permafrost conditions, ground types, construction considerations, and methods of identification of five major terrain divisions, their subdivisions, and their associated lakes in the vicinity of Northway in the Upper Tanana River basin of eastern Alaska. The five terrain divisions are river flood plains, sand dunes, lake-sediment terraces, alluvial fans, and bedrock areas. A major purpose of the investigation resulting in this report was to determine the relationship of permafrost to terrain types in the Northway area so that ultimately criteria can be established for the prediction of permafrost conditions in areas of possible military importance not accessible for ground investigation. Emphasis was placed on the use of aerial photographs in the analysis of terrain divisions.

WAR DEPARTMENT, "Frost Investigation, First Interim Report, December 1944", Frost Effects Laboratory, Boston District, U. S. E.

This report presents the status of the frost investigation program and results of tests by the Boston District, the Missouri River Division, and Great Lakes Division to 1 December 1944.

WAR DEPARTMENT, "Frost Investigation, Second Interim Report, April - 1945", Vols. I and II, Frost Effects Laboratory, Boston District, C. E.

This report presents the additional data, 1 December 1944 to 15 March 1945, secured since submission of the First Interim Report for each airfield selected for investigation in the Boston District, Missouri River Division and Great Lakes Division.

WAR DEPARTMENT, "Frost Investigation, 1944", Corps of Engineers, Boston District, January 1946

This is a report of the frost investigations performed at Dow Field, Bangor, Maine, during 1944, for the purpose of determining the influence of frost action on the subgrade soils beneath both rigid and flexible pavements at Dow Field upon the gross plane weight evaluation of these pavements. The testing program consisted of the excavation of test pits, explorations to determine base and subgrade soil profile under test areas, application to paved surfaces of controlled traffic during frost melting period, and the performance of pavement bearing tests during the frost melting period.

WAR DEPARTMENT, "Frost Investigation, 1945-1946", Corps of Engineers, Boston District, June 1946

This is a report on studies of base course treatment to prevent frost action. This report presents (a) a summary of previous investigations performed by others, to study effect of admixtures on frost action; (b) the results of laboratory tests performed to determine suitability of various admixtures and combinations of admixtures; (c) results of laboratory tests to determine whether leaching of salts could be retarded or prevented by the addition of bituminous materials.

WAR DEPARTMENT, "Frost Investigation, 1944-1945, Comprehensive Report", with 15 Appendices, Corps of Engineers, New England Division, February 1947

A comprehensive report covering laboratory work, review of previous investigations, and field studies at 15 airfields in the United States.

WAR DEPARTMENT, "Report on Frost Investigation, 1944-1945", Corps of Engineers, New England Division, April 1947

This report presents a summary of the studies, the observations and tests made, and the conclusions based upon these data including Part XII, Chapt. 4, Ad Interim Engineering Manual. The work presented includes the data obtained in the investigations conducted in 1944 and 1945. The program for 1944-1945 consisted of the following phases: (1) A review and analysis of previous investigations of frost action; (2) Performance of laboratory controlled tests to determine coefficients of heat transfer of various soils; (3) Observation and testing of effect of frost action during winter 1943-1944 and 1944-1945 under paved and turfed airfield areas; and (4) the review and analysis of results of investigations performed.

WAR DEPARTMENT, "Frost Investigation, 1944-1945", Corps of Engineers, Missouri River Division, July 1945

Report of investigation to determine the development of frost action in subsurface pavement elements as affected by varying conditions of weather, soils, and groundwater. The airfields studied were: Sioux Falls Airfield; Fairmont Airfield; Great Bend Airfield; Garden City Airfield; and Pratt Airfield.

WAR DEPARTMENT, "Airfield Pavement Design: Construction of Airfields on Permanently Frozen Ground", Corps of Engineers, Office, Chief of Engineers, October 1946, Engineering Manual for War Department Construction, Part 12, Chapter 7

Design for conditions in permafrost regions, including design for freezing as well as thawing of foundations, for roads, airfields, and structures.

WATKINS, W. I., "Discussion on Frost Heaving", (Abstracted), Proceedings, Highway Research Board, Vol. 11, Pt. 1, pp. 165-168, 1931

A discussion on the theory of frost heaving.

WATKINS, W. I. and AARON, H., "The Soil Profile and Subgrade Survey", Public Roads, Vol. 12, No. 7, pp. 51-64, September 1931

A study of the relationship between frost boils and soil structure and the soil profile.

WATSON, W., "Change of Volume During Fusion, and Latent Heat of Fusion", A Textbook of Physics, Paragraphs 209 and 211, pp. 236-239, 1911, Longmans, Green and Co., New York

Volume change of water changing to ice and latent heat of fusion.

WERNECKE, LIVINGSTON, "Glaciation, Depth of Frost, and Ice Veins of Kero Hill and Vicinity, Yukon Territory", Engineering and Mining Journal, Vol. 133, pp. 38-42, 1932

Frozen zone studied in mine shafts. One shaft 400 ft, another 300 ft without passing out of frozen ground. Where thawed ground is encountered below permafrost, water under hydraulic pressure also encountered which gives rise to mining difficulties. Ice veins observed, but they do not exceed 6 in. Several photographs used to illustrate veins and crystals. Author then discusses occurrences and effect of ice to greater detail.

WEST, E. S., "Effect of Soil Mulch on Soil Temperature", Journal of the Council for Scientific and Industrial Research (Australia), Vol. 5, pp. 236-246, 1932

Results of an experimental study of soil temperatures and temperature amplitudes in cultivated and uncultivated soils.

WILFORD, H. D., DOWNEY, E. R., BRIGGS, G. F., HOGENTOGLER, C. A. JR., KNIGHT, J. A., ELLEMAN, J. A. and BURGGRAB, F., "Uses of Calcium Chloride in Road Stabilization", Proceedings, Highway Research Board, Vol. 18, Pt. 2, pp. 209-256, 1938

This symposium on the use of calcium chloride in stabilization

includes a table showing the relation between the freezing point of water and percent calcium chloride in the water.

WILLIAMS, A. M., "What Causes the Spring Break-up?", Better Roads, Vol. 15, No. 11, pp. 22-23, November 1945

Description of the effect of an early deep freeze followed by a fall thaw creating a "frost partition" above which water is trapped causing portland cement concrete to pump and causing distress to other types of roads. Three remedial measures are described.

WILSDON, B. H., "Problems of Porous Bodies and Their Behaviour as Building Materials", Journal of the Society of Chemical Industry (London), Vol. 53, pp. 397T-402T, 28 December 1934

A discussion of the principal factors which affect frost resistance of building brick. Included are: permeability, suction, measurement of hydrostatic pressures in unsaturated porous bodies, capillary rise in a porous medium, mechanical effects produced by liquids in porous bodies, and mechanical effects produced by the formation of solids in porous bodies. Apparatus for determining suction pressure and also for measuring pressure deficiency by an osmotic method are described.

WILSON, J. R., "Frost Action on Rigid Pavements", Engineering News-Record, Vol. 80, No. 13, p. 626, 28 March 1918

The author advocates deep drainage, sufficiently deep to extend below frost line and also to lower the line of saturation below the subgrade. No data are given.

WILSON, WALTER K. JR., Colonel, C.E., "The Problem of Permafrost", The Military Engineer, April 1948, Vol. XL, No. 270, pp. 162-164

Describes study of permafrost started in 1945 by Corps of Engineers, St. Paul District. Field work in Alaska includes studies of airfields constructed during World War II, an experimental plot constructed near Fairbanks, weather and ground temperature data from various points, and development of methods for locating airfield sites from aerial photographs. Laboratory studies of thermal properties of soils were made at the University of Minnesota. Object of studies is to develop criteria for design and construction of airfields in arctic and subarctic regions.

WINN, H. F., "Frost Action in Stabilized Soil Mixtures", Proceedings, Highway Research Board, Vol. 18, Pt. 1, pp. 264-290, 1938

The results of a laboratory study to determine the frost-heaving characteristics of a clay, a washed concrete sand, a pit-run gravel and graded soil mixtures molded without admixtures and with different percentages of 11 different "stabilizers". The stabilizers included various grades of liquid bituminous materials, portland cement, calcium and sodium chlorides and calcium oxide. The report describes laboratory equipment, apparatus and experimental procedure

and shows the effect of admixtures on heaving.

WINTERKORN, H. F. and FEHRMAN, R. G., "The Effect of Freezing-Thawing and Wetting-Drying Cycles on the Density and Bearing Power of Five Soils", Proceedings, Soil Science Society of America, Vol. 9, pp. 248-252, 1944

Results of accelerated laboratory tests to determine the effect of: (1) immersion only; (2) twelve cycles of freezing and thawing; (3) twelve cycles of freezing and thawing with subsequent water immersion for 12 days; (4) twelve cycles of wetting and drying; and (5) twelve cycles of freezing and wetting on the density, moisture content and California Bearing Ratio of the B horizon soils from 5 Missouri, Oklahoma and Kansas soils.

WINTERMEYER, A. M., "Percentage of Water Freezable in Soils", Public Roads, Vol. 5, No. 12, pp. 5-8, February 1925

Apparatus and methods of testing are presented for determination of freezing point of soils by the dilatometer method. Experimental data from tests on 150 soils are given.

WHITE, A. C., "Frost Boils and Their Elimination", Public Works Magazine, Vol. 59, No. 1, pp. 10-11, January 1928

Description of types of subsurface drainage installations which the author claims have been successful in Moor County, Minnesota.

WOODS, K. B., "Frost Action", Aims and Activities of the Joint Highway Research Project, Purdue University Engineering Bulletin, Vol. 24, No. 2 (Research Ser. No. 71, Highway Research Bulletin 3), pp. 35-37, 41-43, 48-49, March 1940

Pictorial and graphical representation and conclusions of frost studies at Purdue University. The data are published in the following reference: Winn, H. F., "Frost Action in Stabilized Soil Mixtures", Proceedings, Highway Research Board, Vol. 18, Pt. 1, pp. 264-290, 1938.

WOODS, K. B., "Report of Committee on Frost Heave and Frost Action in Soil", Presented at 27th Annual Meeting, Highway Research Board, December 1947

Effectiveness of treatments in which calcium chloride was placed in holes bored through flexible and rigid type pavements into the subgrade or in trenches along the pavements in frost-heave areas. Also studies of permanency of calcium chloride admixtures.

WOODS, K. B., HITTLE, JEAN E., and FROST, R. E., "Use of Aerial Photos in the Correlation Between Permafrost and Soils", The Military Engineer, Vol. XL, No. 277, November 1948

This article gives a brief discussion of the methods and results obtained in the use of air-photo patterns to identify soils and permafrost for site selection, thus concentrating field reconnaissance on the best sites available. It is based upon 3 years' field work by Purdue University in Alaska, under contract with the

Corps of Engineers, St. Paul District Office.

WYCKOFF, L. B., "Some Observations on Effect of Frost in Raising Weight", Engineering News-Record, Vol. 80, No. 13, pp. 627-8, 28 March 1918

The author cites cases of a brick wall, weighing 2000 psf, raised  $3/4$  in. and several piers supporting columns and roof trusses raised  $1/2$  to  $2-3/4$  in. by frost action.

x. WATER SUPPLY, HYDROLOGY, RUNOFF

BRIDGEMAN, P. W., "Effect of Pressure on the Freezing Point of Water", Smithsonian Physical Tables, Smithsonian Miscellaneous Collections, Vol. 71, p. 200, 1921

Table showing the effect of pressure on the freezing point of water.

ELLSWORTH, C. E. and DAVENPORT, R. W., "Surface Water Supply of the Yukon-Tanana Region, Alaska", U.S.G.S. Water Supply Paper 342

General features of area -- geology, geography, climate, vegetation (including map) are covered. Runoff data for various creeks in vicinity included in tables. Yukon River, Forty Mile River, Mission Creek, Seventy Mile River, Birch Creek, Tanana River, and Tolvana River basins are described in detail. Several maps included within report. Topographic maps showing gaging stations, also some sketch maps, i.e., distribution of vegetation in region covered. Also bibliography of Government papers on area covered. (About 50 papers listed.)

FARRELL, J. W. B., "Winter Precautions at Regina, Saskatchewan", Water Works Engineering, 26 December 1945, p. 1501, Vol. 98, No. 26

This article discusses the problems of water works maintenance at Regina.

GARSTKA, WALTER U., "Hydrology of Small Watersheds Under Winter Conditions of Snow and Frozen Soil", Transactions, American Geophysical Union, 1944, p. 838

Readings during three winters at East Lansing, Michigan. Very good report of conditions, also good data. Could possibly be used to check rate of thaw, snow-melt, runoff from frozen soils.

GERDEL, R. W., "The Dynamics of Liquid Water in Deep Snow-Packs", Transactions, American Geog. Union, Vol. 26, 1945

Provides good data on thermal and water quantity of snow.

HURST, W. D., "How Winter Problems are Handled at Winnipeg, Canada", Water Works Engineering, 12 December 1945, pp. 1432-1435, Vol. 98, No. 25

This article discusses water works maintenance at Winnipeg. The author points out trouble that developed with one type of hydrant because condensation moisture collected beneath the operating nut and froze onto its bearing. Ingenious

solution of this difficulty is described. Other operating experiences are recounted.

LEWIN, JOSEPH D., "Dams in Permafrost", Public Works Magazine for: May 1948, pp. 22, 23 and 32; June 1948, pp. 33-34; July 1948, pp. 57-58

Series of articles on the construction of dams in areas such as Alaska and northern Canada where permanently frozen ground is encountered. Foundation design, including the effect of ice and other factors, is discussed. References made to Russian articles on permafrost. Includes illustrations taken from publications of Corps of Engineers, D. A. Bibliography.

LEWIS, M. R., "Rate of Flow of Capillary Moisture", U. S. Dept. of Agriculture, Technical Bulletin 579, October 1937, 29 pp.

The results of experimental studies in which water was added at various predetermined rates to one end of a number of soil columns which were exposed at the other end to a current of air maintained at a constant temperature and humidity. The purpose of the experiment was to determine the distance through which water, in appreciable quantities, can be moved by capillary action in a range of moisture between the field capacity and the permanent wilting percentage. Data are given and discussion included on effect of soil type and gravity on rate of flow, and moisture content gradient for different rates of flow.

Bibliography.

MABEE, W. C., "Lessons from the Winter of 1935-1936", Journal, American Water Works Association, Vol. 29, No. 1, 1937

Discusses the effects of an extremely cold winter on the freezing of water service lines. It was stated that in a normal winter in Indianapolis 200 degrees of mean daily temperature below 32° F accumulated, whereas in the winter of 1935-1936, 885 degrees accumulated. Two thousand or 2.7 percent of all private lines froze and these were mostly those which had less than 54 in. cover. Practically all thawing of pipes was done with gasoline motor-driven generators. The most satisfactory condition was at 40 volts with the average of 15 to 20 minutes of current application at 300 amperes to thaw a service. This article includes a graph showing accumulated degrees of mean daily temperature below 32° F and depth of frost penetration and number of frozen services through the winter months.

MEINZER, O. E., "The Occurrence of Ground Water in the United States", U.S.G.S. Water Supply Paper No. 489, pp. 30-63, 1923

The author describes various types of water tables; and the capillary fringe; the capillary rise; the yield and water retention in various types of soils.

PAULSON, JOSEPH B. JR., "A Method of Calculating the Effect of Snow on Runoff During Rainstorms", Transactions, American Geophysical Union, 1944, p. 17

Appears to be good method. Gives resulting runoff intensity

which exceeds sum of rain and snow-melt intensities due to storage of snow-melt.

PLUMMER, F. L. and DORE, S. M., "Soil Mechanics and Foundations", pp. 131-140, 353-7, 1940, Pitman Publishing Corp., New York

This text includes discussion of heaving of highway slabs, ice segregation, movement of water to form ice crystals, effect of water table level, thawing of frozen soil, and prevention of frost heaving.

ROCHE, M. A. and MITCHELL, M. R. C., "Water Works and Sewerage in the Far North", Public Works Magazine, August 1948, pp. 21-23

A. Unusual Distribution System at Flin Flon, Manitoba, by M. A. Roche. Permanent frost exists here between 1 and 16 ft below the surface. Water pumped through 13,000 ft of 20-in. woodstave pipe has not frozen in 18 years. Heating required on one occasion. Storage tanks and utilidors for distribution are steam heated. Distribution lines are in 4000-ft circuits in which water is circulated continuously. Steam is used to hold temperature at not less than 38° F.

B. Water and Sewerage at Sherridon, Manitoba, by M. R. C. Mitchell. Water mains and sewers are laid close together in trenches about 8 ft below the ground surface or together with steam pipes on the surface in wooden boxes packed with sawdust. The water mains are discharged into the dead ends of sewers to prevent freezing. Sewers laid in boxes are cast iron pipe and those buried in the ground are vitrified clay. The cost of heating the pipes in the boxes is quite high. Boxes inclosing pipes, in general, are large enough to permit a man to work inside without opening the box from the outside.

ST. AMAND, PIERRE, "The Central Alaska Earthquake Swarm of October 1947", Transactions, American Geophysical Union, Vol. 29, No. 5, October 1948

The earthquake swarm of October 1947 is discussed. Investigation of the activity is described. Photographs of earthquake activity are included along with a isoseismal map and a plot of epicenters. The only item of interest insofar as permafrost is concerned is the following statement regarding wells: "Increased turbidity was observed in many wells. The Brazil family, residing between Fairbanks and College, reported an increase in their well water. The well at the Experimental Farm began producing copiously for the first time since it was drilled." It may be also noted that wells that had been pumped before began to discharge water freely at Nenana.

TABER, STEPHEN, "Surface Heaving Caused by Segregation of Water Forming Ice Crystals", Engineering News-Record, Vol. 81, 1918, No. 15, 10 October, pp. 683-4

A discussion of articles by J. L. Harrison, Engineering News-Record, Vol. 80, No. 9, pp. 418-420, 28 February 1918, and

C. D. Norton, Engineering News-Record, Vol. 80, No. 22, p. 1058, 30 May 1918, in which Taber disputes their claims and presents his hypothesis on the formation of ice layers and the cause of frost heave.

TABER, S., "Freezing and Thawing of Soils as Factors in the Destruction of Road Pavements", Public Roads, Vol. 11, No. 6, pp. 113-132, August 1930

A summary of Taber's comprehensive studies of frost action in soils. Apparatus and test methods are described. Freezing effects in closed and open systems; direction of growth of ice crystals; grain size; soil composition; water supply; rate of cooling; effect of load pressure; the mechanics of frost heaving in open systems; and freezing and thawing of soils under pavements are discussed.

THEIS, C. V., "Report on Water Supply", Fort Belvoir Engineer Board, Fort Belvoir, Va., November-December 1943

This is a report on water supply at Edmonton Satellite Field, Naino, Fairbanks District, Naino, and other places in Alaska and Canada.

THE ENGINEER SCHOOL, "Water Supply in Arctic, Subarctic, and Antarctic Regions", The Engineer Center, Fort Belvoir, Va., June 1948, Restricted.

This report presents the results of a study of arctic, subarctic and antarctic water supply problems and methods. Its purpose is to furnish information needed to develop water supply methods at military bases and during field operations, and also to estimate future Army requirements. Much of the information was obtained from official reports of military operations by the armed forces of the U. S. and Canada and from Government publications of both nations. Various subjects covered are types of natural water resources; civilian water supply methods; military and naval water supply; recent developments in field water supply equipment, etc.

WAR DEPARTMENT, "Water Supply and Water Purification", Technical Manual TM 5-295, 1942

This manual discusses those basic principles of water supply and water treatment which pertain to both civilian and military practice and, in addition, the expedients necessary in the field. Discussion includes the following topics: Sources of Water and its Impurities; Development of Water Sources; Water Quality and Purification; Storage, Distribution, and Measurement of Water; and Operation.

WAR DEPARTMENT, "Ground Water Supply for Military Operations", Technical Manual TM 5-296, 1 February 1944

This manual presents information on the occurrence of groundwater and the location of groundwater supplies for military purposes. Covers the occurrence of water in rocks, relationships between rock structure and groundwater movement, the

location of usable water in coastal zones and desert regions, the occurrence of springs, the quality of water to be expected from various sources, and methods of groundwater reconnaissance.

y. WEATHER, PRECIPITATION, AIR TEMPERATURE

ARMY AIR FORCES, "Weather Stations -- In Alaska and Western Canada", 15 February 1945, 16th Weather Region, Regional Control Office

This pamphlet includes the following data: Part I -- List of Weather Stations in Alaska and Central and Western Canada; Part II -- Alphabetical List of Call Letters for Weather Stations in Alaska and Central and Western Canada; and Part III -- Numerical List of Index Numbers for Weather Stations in Alaska and Central and Western Canada.

COLEMAN, A. P., "Ice Ages Recent and Ancient".

"The largest tree now growing in Spitzbergen is a willow which scarcely rises three inches above the ground. The Arctic regions have enjoyed genial periods and some parts of the tropics have suffered Arctic cold, showing that in the past there have been very important variations of climate. Seams of excellent coal.....and great fossil leaves belonging to trees of a warm climate in beds of Cenozoic age are found in Spitzbergen."

DARTON, N. H., "Geothermal Data of the United States", Bulletin 701, U. S. Geological Survey

This bulletin is chiefly concerned with temperature measurements made with maximum self-registering mercury thermometers lowered bulb end up into wells, mines, etc. There are many tabulations of temperatures and reference is made to J. Prestwicks' "Underground Temperatures", Royal Society, London Proceedings, Vol. 41, pp. 1-116, 1886.

DEPARTMENT OF TRANSPORT, "Meteorology of the Canadian Arctic", 1944, Air Services Branch, Meteorological Division, Canada

This manual contains a summary of the reports of meteorological observations which have been taken in the Canadian Arctic, together with an analysis of upper air conditions prevailing in this region. It is necessarily incomplete, chiefly because no long series of observations is available for this territory. Most of the observing stations are concentrated in the southeastern part of the Archipelago, leaving large areas of Canadian territory within the Arctic Circle untouched. Tables and graphs are included showing monthly values of temperature, precipitation, wind and fog at certain selected stations.

ENO, F. H., "The Influence of Climate on the Building, Maintenance and Use of Roads in the United States", Proceedings, Highway Research Board, Vol. 9, pp. 216-223, 1929

Charted maps of the U. S. giving winter temperature data and suggestions for research on frost action.

HAND, IRVING, F., "A Summary of Total Solar and Sky Radiation Measurements in the United States", U. S. Dept. of Commerce, Weather Bureau, Monthly Weather Review, Vol. 69, April 1941, pp. 95-125

This paper presents a summary to date of the total solar and sky radiation measurements made by the Weather Bureau and cooperating institutions and individuals; the data are presented in tabular form, and also graphically by 18 isopleths.

HAND, IRVING, F., "Review of United States Weather Bureau Solar Radiation Investigations", U. S. Dept. of Agriculture, Weather Bureau, Monthly Weather Review, Vol. 65, December 1937, pp. 415-441

This paper presents a summary to date of the methods employed and the results obtained in the solar radiation investigations conducted by the Weather Bureau. Many data are here published for the first time, while several tables and charts previously published in the Monthly Weather Review are revised and brought up to date. Numerous references to literature are included.

HAND, IRVING F., "Observations of Radiation Penetration Through Snow", U. S. Dept. of Commerce, Weather Bureau, Monthly Weather Review, Vol. 70, February 1942, pp. 23-25

The penetration of solar radiation through various thicknesses and qualities of snow is of importance in many hydrological and other problems. The authors made some measurements at Brighton, Utah. These measurements constitute only a preliminary study but results have been sufficient to show the value that further work would have.

KIMBALL, D. A., RUHNKE, G. N. and GLOVER, M. P., "A Comparison of Temperatures in Air and at Various Depths in a Light Sandy Soil in Southern Ontario", Scientific Agriculture (Canada), Vol. 14, No. 7, pp. 353-9, March 1934

An example is given of recorded temperature data taken with recording thermograph of the two-pen type with mercury in steel cables. Tabulated data are given showing average monthly temperatures of air and of the soil at depths of 4, 12 and 24 in. from July 1930 to June 1932.

KINCER, J. B., "Precipitation and Humidity", Atlas of American Agriculture, Pt. 2 (Climate), Sec. A (Precipitation and Humidity), Advance Sheet No. 5, 15 March 1922

Charted maps of the U. S. giving data on precipitation and humidity on basis of monthly, seasonal and annual averages. Records for the uniform 20-year period, 1895-1914, were used in constructing the principal charts and diagrams.

KINCER, J. B., "Temperature, Sunshine and Wind", Atlas of American Agriculture, Pt. 2 (Climate), Sec. B (Sunshine and Wind), Advance Sheet No. 7, November 1928

Charted maps of the U. S. and diagrams giving data on temperature, sunshine and wind, on basis of monthly, seasonal and annual values. Records cover the uniform 20-year period, 1895-1914.

SMITH, ALFRED, "Comparison of Daytime and Nighttime Soil and Air Temperatures", Hilgardia, 4:10, December 1929, pp. 241-272

A discussion of the relationship between the rate of percolation and soil temperature and a charted summary of soil temperatures. This article is supplementary report to that published in Hilgardia, Vol. 4, No. 3, pp. 77-112, May 1929.

TANNEHIL, IVAN R., "Weather Around the World", Princeton University Press, Princeton, N. J., 1943

This book gives average monthly temperatures for many places in the world and some other information.

U. S. DEPARTMENT OF AGRICULTURE, "Climate and Man", Yearbook of Agriculture, Pt. 5, Climatic Data, with Special Reference to Agriculture in the U. S., pp. 664-1210, 1941

Charted and tabular data on temperature and precipitation up to 1938. Includes 46 charted maps of the U. S. as well as climatic summary tables, precipitation and temperature tables, special frost tables and supplementary climatic notes for each state.

U. S. WEATHER BUREAU, "Climatic Summary of the United States", Bulletin W, Sec. 1-105, 1930

Climatic data from the establishment of stations to 1930 inclusive. See also monthly summaries of weather data by states for climatic data from 1930 to the present.

VISHER, S. S., "Climatic Laws", 1924, 96 pp., John Wiley and Sons, New York

This book contains 90 generalizations with numerous corollaries concerning the geographic distribution of temperature, wind and moisture. No specific data of value in the solution of the frost action problem are given.

WAR DEPARTMENT, "Report of Trip to Weather Stations in Alaska", 2 August-14 October 1945, by Captain Donald McDonald III, Corps of Engineers, St. Paul District

An unpublished report of trip made by the writer to obtain information which would be of value in the making of ground temperature installations at various weather stations and to obtain data required as ground temperature equipment procurement information, including the selection of sites for the temperature test holes. Includes photographs, descriptions and drawings of the weather stations visited.

## V Conclusions

18. CONCLUSIONS. The contract with The Stefansson Library has provided a search by competent translators of Russian literature which may be pertinent to the Permafrost Investigation. The brief summaries and translations of the Russian literature,

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available at this time, have confirmed many of the ideas and theories developed in the study of permafrost. Although no new fundamental concept of the problem has been discovered, the many angles of approach and statement obtained from articles given in both the Russian and English bibliographies have helped to clarify and expand the understanding of the subject.